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Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations

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TERMS

bgs	below ground surface
BHI	Bechtel Hanford, Inc.
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
CY	calendar year
DOE	U.S. Department of Energy
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FH	Fluor Hanford, Inc.
FY	fiscal year
HEIS	Hanford Environmental Information System
ISRM	In Situ Redox Manipulation
IX	ion exchange
LWDF	Liquid Waste Disposal Facility
MCL	maximum contaminant level
MR3	MR3 Systems, Inc.
OU	operable unit
PNNL	Pacific Northwest National Laboratory
QC	quality control
RAO	remedial action objective
ROD	Record of Decision
RPD	relative percent difference
SAP	sampling and analysis plan
TPH	total petroleum hydrocarbons

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

Fluor Hanford, Inc. (FH) is currently operating six groundwater pump-and-treat systems across the Hanford Site. Four systems address groundwater in the 100 Areas: the 100-HR-3 Operable Unit (OU) system, which is treating hexavalent chromium at three sites (100-D and 100-H Areas); the 100-KR-4 OU system, which is also treating hexavalent chromium; and the 100-NR-2 OU system, which is treating strontium-90. A treatability test for a new pump-and-treat system, the 189 L/min DR-5 system developed by MR3 Systems, Inc. (MR3), was added in the 100-D Area in calendar year 2004 (CY04). Two pump-and-treat systems are remediating groundwater in the 200 West Area: the 200-UP-1 OU system, which is treating technetium-99, uranium, carbon tetrachloride, and nitrate; and the 200-ZP-1 OU system, which is treating carbon tetrachloride, chloroform, and trichloroethene.

This annual summary report discusses the groundwater remedial actions in the 100 Areas, including interim remedial actions at the 100-HR-3, 100-KR-4, and 100-NR-2 OUs (Figure 1-1). A detailed description of the progress and performance of the In Situ Redox Manipulation (ISRM) barrier is reported separately in another annual summary report (DOE-RL 2005b [pending issuance]).

The interim remedial actions chosen for the 100-HR-3 and 100-KR-4 OUs are pump-and-treat systems that use an ion-exchange (IX) medium for contaminant removal. The systems were designed to achieve three remedial action objectives (RAOs), as well as specific operational and aquifer performance criteria described in the interim remedial action Record of Decision (ROD), *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site (Interim Remedial Actions)* (EPA et al. 1996). The three RAOs are identified as follows:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.
- **RAO #3:** Provide information that will lead to a final remedy.

The *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1, and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999) specifies the selected remedy and activities for the 100-NR-2 OU. Some of these remedial activities are ongoing actions, such as the pump-and-treat operation specified in the *Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy Hanford Site, Richland, Washington* (Ecology and EPA 1994). The 100-NR-2 RAOs are summarized as follows:

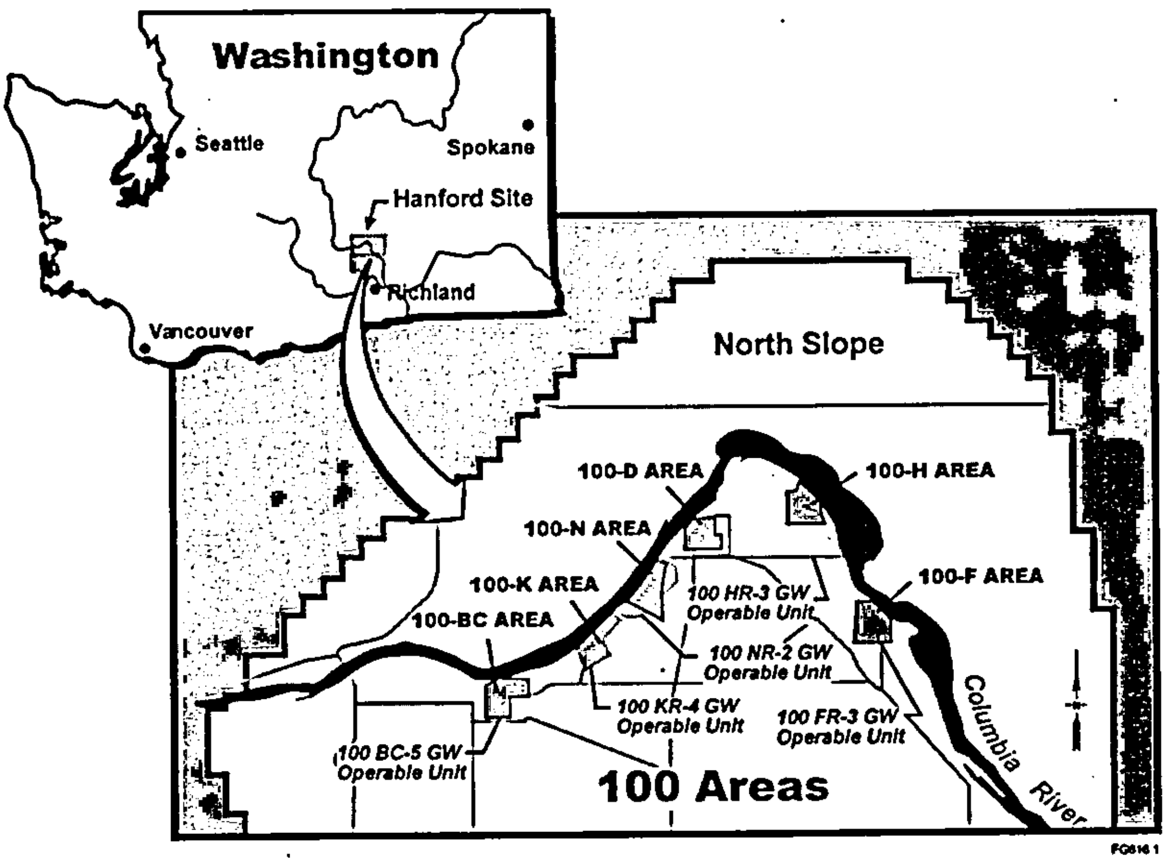
- **RAO #1:** Maintain beneficial uses of the Columbia River and protect the aquifer by reducing contaminant concentrations in the 100-NR-2 groundwater.
- **RAO #2:** Evaluate commercially available treatment options for strontium-90.
- **RAO #3:** Provide data necessary to set demonstrable strontium-90 cleanup standards.

This report discusses progress toward the RAOs in the respective conclusion section for each OU.

This report is organized into three major sections, each presenting the annual summary and performance evaluation for the three respective OUs. Section 2.0 discusses the 100-HR-3 OU, Section 3.0 discusses the 100-KR-4 OU, and Section 4.0 discusses the 100-NR-2 OU. An evaluation of costs is presented in Section 5.0, and the references cited in this report are included as Section 6.0.

This report provides a summary of major CY04 activities, major trends, and significant differences between 2003 and 2004 for each OU. An updated conceptual model is also presented for the 100-NR-2 OU. Additional supporting information is included in Appendices A through M.

Figure 1-1. Location of 100 Area Groundwater Operable Units.



2.0 100-HR-3 OPERABLE UNIT PUMP-AND-TREAT SYSTEM

The 100-HR-3 pump-and-treat facility is located in the north-central part of the Hanford Site along the Columbia River. The 100-HR-3 OU represents the groundwater underlying the source OUs that are associated with the 100-D and 100-H Reactor areas and the adjacent 600 Area (Figure 2-1). Groundwater extraction systems were installed at the 100-D and 100-H Reactor areas in June 1997, with a common treatment facility in a surplus building located near H Reactor. A stand-alone pump-and-treat system, DR-5, was installed in 2004 to treat a new source located in the central portion of the 100-D Area.

Monitoring and extraction well locations for the 100-D Area are shown in Figure 2-2, and the 100-H Area well locations are shown in Figure 2-3. Appendix A provides a history of operations and supporting documents used in the development of the 100-HR-3 pump-and-treat system. Site conceptual models are presented in Appendix B

This section provides the CY04 annual summary report for pump-and-treat operations in the 100-HR-3 OU, as required by the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996b). Section 2.1 briefly summarizes activities within the OU potentially impacting activities associated with the pump-and-treat system. Section 2.2 summarizes the treatment system's performance. Sections 2.3 and 2.4 review hydraulic conditions, provide capture zone analysis through numerical modeling, and evaluate the contaminant concentrations for the 100-D and 100-H Areas. Section 2.5 discusses quality control (QC) results for groundwater samples. Sections 2.6 and 2.7 provide conclusions and recommendations for the pump-and-treat system. Cost information is presented separately in Section 5.0.

2.1 SUMMARY OF ASSOCIATED ACTIVITIES

A summary of remedial actions for the 100-HR-3 OU and associated contaminant source control activities are discussed in the following subsections.

2.1.1 100-D/DR Area

Multiple leaks and spills of sodium dichromate stock solution (hexavalent chromium) occurred in the 100-D Area during the reactor's operating years (1944 to 1969). Continuing movement of residual soil contamination from these sources is assumed to account for the widely distributed and persistent groundwater contamination beneath much of the 100-D Area. Efforts have been underway since 1997 to reduce releases to the river using a pump-and-treat system and a permeable reactive barrier (which was completed in 2003). In October 2003, an area of elevated hexavalent chromium contamination moved into this area, where concentrations previously had been low. Accordingly, a coordinated effort was initiated in the fall of 2003 that included (1) source identification/removal (Bechtel Hanford, Inc. [BHI]), (2) elimination of artificial recharge as a potential driving force, and (3) groundwater remediation/containment to reduce releases to the river.

Progress in the 100-D/DR Area during 2004 included the following activities:

- Leakage from an extensive network of pressurized water lines is believed to be a potential driving force for transport of soil contaminants to the groundwater. These water lines run through suspect dichromate spill sites in the 100-D Areas. This potential driving force for chromium contamination in the vadose zone was significantly reduced in CY04 by capping all of the water lines and sealing about 75% of those that may have leaked. The remaining water lines will be eliminated after demolition and removal of existing buildings.
- There were renewed efforts to locate and remove soil contamination in fiscal year 2004 (FY04). BHI excavated more than 20 test pits along suspected spill sites southeast of the 182-D reservoir. Dichromate stock solution was offloaded from railroad tank cars in this area and then transferred through buried pipelines. The test pits were sampled with depth, down to 4.6 m below grade and analyzed for soluble or leachable hexavalent chromium. No significant soil contamination was identified with this extended soil survey. Either the source(s) are deeper than 4.6 m below ground surface (bgs) or very localized sources exist but have not yet been discovered.
- Groundwater remedial actions are focused on three separate areas: (1) the northeast sector (the original pump-and-treat), (2) a new "hot spot" pump-and-treat system in the central portion of the 100-D Area, and (3) the southwest sector where a 660-m-long permeable reactive barrier is in place (this is known as the ISRM barrier).

  Activities during 2004 in these areas included the following:

  - Operation of the initial pump-and-treat system. This system continues to contain the chromium plume in the northeastern sector where salmon spawning beds are known to be located off the shoreline.

    Over 164 million L of groundwater were extracted from the 100-D Area during 2004 and treated in the 100-H treatment plant. Average 100-D influent concentration was 193.5 μg/L, and a mass of over 31 kg of chromium was removed. Since startup, over 200 kg, or approximately one-third of the estimated mass in 100-D groundwater (DOE-RL 1997a), have been removed. Average removal efficiency was 95.2%, and the system operated 99.1% of the available run-time.

  - Startup of the new DR-5 pump-and-treat system. This system became operational in late July 2004 and was installed to address chromium-contaminated groundwater that passes the ISRM barrier to the northeast. The pump-and-treat approach was selected instead of extending the ISRM barrier because of unresolved ISRM barrier performance issues. The direction to construct the new pump-and-treat system is specified in *Direction to Implement the Requirements Under the 100-KR-4 Records of Decision (ROD) for the 100-D Area Chromium Plume* (DOE-RL 2004b).

    The new pump-and-treat plant consists of a self-contained, modular IX treatment system that receives groundwater from three extraction wells (199-D5-20, 199-D5-32, and 199-D5-37) (Figure 2-2). These wells are located on the downgradient edge of the plume. One injection well (199-D5-42) returns the treated groundwater to the aquifer. The treatment plant is housed in the 186-D Building, and contains four IX vessels (a lead, lag, polish, and standby vessel). Additional tanks are used to store and mix chemicals for onsite regeneration of the IX medium.

Over 20 million L of water were treated in the first 6 months of CY04, removing 19 kg of chromium. Average influent concentrations were near 958 μg/L, with a removal efficiency of over 99%. Plans for CY05 include expansion of the treatment plant's capacity to accommodate additional extraction wells. Even with the small initial test unit, it is anticipated that more chromium will be removed per year than by the existing 100-HR-3 (100-D and 100-H) extraction/treatment systems. This new pump-and-treat system more than doubles the chromium removal rate from 100-D groundwater.

The new self-contained system at 100-D was designed and constructed by MR3 and uses their HCR-48 IX medium to capture the chromium. The advantage of the MR3 system is that considerable potential cost savings are achieved because no spent resins are shipped offsite for regeneration. The MR3 medium is regenerated in-place by periodically treating the IX columns with a reducing agent and acid. The waste stream from the regeneration process contains trivalent chromium hydroxide, which is converted to a solid cake. The cake is stored at the treatment plant site until it is shipped to the Environmental Restoration Disposal Facility (ERDF) for disposal.

- The ISRM was installed to address the chromium plume in the southwestern portion of the 100-D Area. Installation and treatment of the last of 66 injection wells was completed in 2003. While most of the barrier has functioned as planned, the northeastern end has exhibited a premature decrease in reduction capacity. Two expert panel reviews were held in 2004 to identify possible causes of loss in reductive capacity and to identify possible mitigative actions. Additional details concerning the status of these activities are available in *Fiscal Year 2004 Annual Summary Report for the In Situ REDOX Manipulation Operations* (DOE-RL 2005b [pending issuance]).

- Upgrades to the performance monitoring system continued in CY04. Several new wells were installed, including 199-D8-73, 199-D8-88, and 199-D5-92 (Figure 2-2). In CY05, well 199-D5-92 will replace well 199-D5-37 as an extraction well because of the low production rate in the latter well (11 L/min). In addition, in CY05 monitoring well 199-D5-39 will be converted to an extraction well. This well is located in the center of the high-concentration area and would support acceleration of remediation for the DR-5 system.

- Aquifer tubes were installed at five new locations from December 2003 through January 2004. The sites where placed along the 100-D Area bench, downstream of the D/DR Reactor pump house. The highest shoreline concentration observed in aquifer tubes in CY04 was 360 μg/L in the central shoreline region. The new DR-5 pump-and-treat system was installed to intercept the plume in this area.

2.1.2 100-H Area

A pump-and-treat system has been operating since 1997 to contain and remove hexavalent chromium in the 100-H Area groundwater. The moderate contaminant concentrations in this area are believed to be related to (1) past leakage from a solar evaporator basin that was used to concentrate wastewater (it has since been demolished), and (2) related to the loss of sodium dichromate-laden reactor coolant water during operations from 1949 to 1965. The steady decline in groundwater chromium concentrations since the start of pump-and-treat operations indicates little or no continuing soil sources. Based on the decline in hexavalent chromium concentrations, the RAO in this OU may be achievable in the near future. The status of the pump-and-treat system's operations, system improvements, and related OU activities for CY04 is as follows:

- The 100-HR-3 IX system was modified to include a sacrificial IX resin column. Previously, natural uranium built up on the lead IX resin column, required that the resin be disposed as a mixed waste at the ERDF rather then regenerated. To avoid the frequent expense of mixed waste disposal and the purchase of new resin, the treatment train's manifold piping was modified to allow the lead vessel to function as a uranium-removal column, thereby protecting the remaining three columns for chromium removal. The remaining three vessels continue to rotate through the normal lead/lag/polish operating line-up. This design modification, instituted in March 2004 at both 100-KR-4 and 100-HR-3, has led to a combined cost savings estimated at $500,000 for CY04, compared to CY03 expenditures for replacing lost resin.
- The extraction and injection well network was reconfigured near the end of December 2004. The purpose of these changes was (1) to accelerate the capture and treatment of a smaller remaining portion of the 100-H plume near the river that is above the RAO of 22 μg/L; and (2) to increase the capture zone efficiency in areas that were previously identified using groundwater modeling. To accomplish this objective, monitoring and compliance wells 199-H4-64 and 199-H4-4 were converted to extraction wells (Figure 2-3); existing extraction well 199-H3-2A was converted to an injection well; and former monitoring well 199-H4-18 was converted to a new injection well. Former injection wells 199-H3-4 and 199-H3-5, located southwest of the reactor building, were scheduled to be taken out of service in January 2005. Injection well 199-H3-3 will continue as an injection well. Field work on this project was completed in January 2005. Figure 2-3 presents the well configuration as described above.

2.2 100-HR-3 OPERABLE UNIT TREATMENT SYSTEM PERFORMANCE

This section describes the 100-HR-3 pump-and-treat system's operation and related sampling activities. Information presented includes system availability, changes to system configuration, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and short-term contaminant comparisons. Additional operational details are found in the identified appendices.

2.2.1 System Modification/Operation

As described in Section 2.1, a new pump-and-treat system has been installed in the 100-D Area. A water leak at the 182-D reservoir created a groundwater mound beneath the reservoir and in the surrounding area. The mound allowed the plume to partially bypass the current pump-and-treat system to the northeast and the ISRM barrier to the northwest. A decision was made to install a freestanding pump-and-treat system, specifically located to capture this plume. Three monitoring wells were installed to help bound the plume, with the additional intention to use these wells as extraction wells. Subsequently, wells 199-D5-20, 199-D5-32, and 199-D5-37 were converted to extraction wells.

To treat the extracted groundwater, an innovative IX system was selected, designed, and constructed for the pump-and-treat system. This system, manufactured by MR3, uses an HCR-48 resin for removing hexavalent chromium. While capital costs are higher initially, this system is expected to reduce treatment costs by eliminating offsite resin regeneration costs.

The MR3 system consists of four, 946-L-capacity resin columns, as well as associated piping, filter banks, equalization tanks, manifolds, and process logic control systems. The installed system is capable of processing up to 189 L/min of groundwater. Groundwater flows through three columns in a lead/lag/polish configuration, with a forth vessel held in standby. Additional equipment includes components for onsite regeneration of the resin, storage of process chemicals, and transfer of liquids internally and to the injection wells.

The new pump-and-treat system began operating the end of July 2004. Through the end of CY04, over 20 million L of groundwater have been treated. Influent concentrations of hexavalent chromium have averaged 958 μg/L, while treated effluent has averaged 2.2 μg/L. In a couple of instances, the effluent concentrations have been as high as 20 μg/L and 100 μg/L, initiating shutdown of the pump-and-treat system. These high concentrations occurred while making operational adjustments and changes using this new technology.

Production rates at extraction well 199-D5-37 have been very low. Well 199-D5-37 only produces 11 L/min, whereas the overall system production rate has been 141 L/min. It appears that well 199-D5-37 is completed in a portion of the aquifer where the hydraulic conductivity is extremely low. To increase the rate of remediation and widen the zone of capture, monitoring well 199-D5-92 will replace 199-D5-37 as an extraction well in FY05. This change will still maintain capture in the area of well 199-D5-37 but will increase the rate of contaminant mass removal.

Other current monitoring wells will be converted to extraction wells in FY05 to capture the high-concentration area of the plume. These additions should accelerate remediation and more effectively reduce risk. Wells that may be converted include 199-D5-39 and 199-D5-43. Figure 2-4 and 2-5 provide system schematics, detailing the current configuration for the 100-D and DR-5 pump-and-treat systems.

A summary of operational parameters and total system performance for the 100-HR-3 pump-and-treat in CY04 are presented below. The new DR-5 pump-and-treat system data are not included in the operational parameters presented below:

Total processed groundwater (million L)[a]:		
	CY04	**Since 1997 Startup**
100-D Area	164.2	1,199.3
100-H Area	153.5	1,066.7
Total	**317.7**	**2,266**
Total mass of hexavalent chromium removed (kg)[a]:		
	CY04	**Since 1997 Startup**
100-D Area	30.1	199.0
100-H Area	3.5	38.6
Total	**33.6**	**237.6**

2004 operational parameters[a]:	
Removal efficiency (% by mass)	95.2
Waste generation (m^3)[b]	81.6
Low-level radioactive waste generation (m^3)	NA
Regenerated resin installed (m^3)	40.8
New resin installed (m^3)	40.8
Number of resin changeouts	36
2004 system availability[a]:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	73
Planned operations (hours)	8,711
Unscheduled downtime (hours)	1
Total time on-line (hours)	8,710
Total availability (%)	99.1
Scheduled system availability (%)	99.9

[a] Does not include system parameters for the new DR-5 pump-and-treat system.
[b] Each IX vessel contains 2.3 m^3 of IX resin.
NA = not available

The operational and system highlights for CY04 discussed below pertain to the existing 100-D pump-and-treat and do not include the operational parameters for the new DR-5 system:

- A combined total of 317.7 million L of groundwater was processed in CY04, which is less than the 416.6 million L processed in CY03. The smaller volume of processed water resulted in a total of 33.6 kg of hexavalent chromium being recovered in CY04 compared to 43 kg in CY03. This decrease may be attributed to lower extraction/injection well efficiency due to well losses associated with scaling (calcium carbonate) or biological fouling.
- The average removal efficiency for CY04 was 95.2%, which is an increase from the 93.8% reported in CY03 (Figure 2-6).
- The 100-D Area influent hexavalent chromium concentration average of 193.5 $\mu g/L$ in CY04 was slightly higher than the CY03 average of 174.5 $\mu g/L$.
- The average CY04 hexavalent chromium concentration of 23.5 $\mu g/L$ for 100-H Area influent was slightly lower than the 27.9 $\mu g/L$ reported in CY03. Trend plots of CY04 influent and effluent concentrations are presented in Figure 2-7.
- With the exception of one sampling event in mid-April, effluent concentrations were consistently below the maximum allowable concentration of 50 $\mu g/L$ for the CY04 reporting period.
- Scheduled system availability for CY04 was 99.9%, which is slightly higher than the scheduled availability reported in CY03. The total availability for CY04 was 99.1%, which is higher than the 97.8% on-line availability reported for CY03. The monthly on-line percentages and method used to calculate scheduled and on-line availability are presented in Figure 2-8.

During CY04, 36 spent IX vessels were changed out. The resin changeouts were performed based on a calculated maximum operating time. The purpose of the limits was to reduce the amount of resin requiring regeneration by maximizing its operational life and limiting the possibility of saturating the resin with uranium and creating a low-level radioactive waste that could not be shipped offsite for reprocessing. The time limits are area-dependent because of the different chemical/radiological characteristics of native groundwater at each well. For the 100-D and 100-H Areas, the time limits are approximately 120 and 90 days, respectively. These time limits were not implemented until late in CY02.

During CY04, the vessels that were changed out yielded 81.6 m^3 of spent resin, which was approximately the same as the 80.5 m^3 reported in CY03. Due to the changes described above to accommodate uranium accumulation, no resin was disposed at the ERDF in CY04.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates are included in Appendix C.

2.3 AQUIFER RESPONSE IN THE 100-D AREA

This section describes the general hydrogeologic conditions in the 100-D Area, the numerical modeling conducted to evaluate the extraction well network, and the changes in contaminant concentrations in monitoring wells.

2.3.1 Hydrogeologic Conditions at the 100-D Area

The hydrogeologic conditions at the 100-D Area are summarized below:

- The prevalent groundwater flow directions are north and northwest, as shown in Figure 2-9. During some spring and summer months, the river elevation is generally higher due to increased run-off and to provide more irrigation water and aid fish migration. This creates a near-shore, short-term groundwater flow reversal from northwest to southeast that is clearly shown in Figure 2-10, when the June and August 2004 river elevations are higher than near-river wells.
- The maximum river stage was 0.152 m lower in CY04 than in CY03; similarly, the minimum Columbia River stage was 0.178 m lower in CY04. Overall, the average Columbia River stage was 0.084 m lower in CY04 than in CY03.
- In 2004, the hydraulic gradient in the area around the original 100-D pump-and-treat system had an average gradient of 0.0005, a maximum gradient of 0.00216, and a net flow direction of 304 degrees azimuth.
- The estimated maximum groundwater flow velocity around the original 100-D pump-and-treat system was 0.16 m/day. This was based on a hydraulic conductivity of 15.2 m/day, an effective porosity of 0.2, with the gradient of 0.00216 derived from a three-point solution of hourly data at wells 199-D8-55, 199-D8-69, and 199-D8-70.
- A typical gradient for November 2004 is calculated from head contours shown Figure 2-9. The distance between monitoring wells 199-D5-39 and 199-D5-36 is 380 m, which is then divided by 0.25 m to give a gradient value of 0.00066.

- The average 2004 extraction well pumping rates ranged from a low of 61.3 L/min in well 199-D8-53 to a high of 120.8 L/min in well 199-D8-68. This continued a downward trend from 84.8 and 185.9 L/min in 2003, and 109.8 and 125.3 L/min in 2002. In support of the new DR-5 pump-and-treat system, three new extraction wells (199-D5-20, 199-D5-32, and 199-D5-37) and one new injection well (199-D5-42) were added to the central portion of the 100-D Area. The largest extraction rate was 110 L/m in well 199-D5-32 (see Appendix D for additional information).
- In 2003, leakage from the 182-D reservoir created a groundwater mound increasing the hydraulic gradient around the reservoir. This resulted in the displacement of the chromium plume radially away from the reservoir and the mixing of groundwater with raw water from the reservoir. In 2004, measures were taken to reduce and eliminate this leakage. These measures included changes to the physical plant and the administrative measure of limiting the reservoir level to no more than 2.4 m. The reservoir and residual mound were monitored by new monitoring wells that were installed for the ISRM barrier project. From the water elevation data collected at these stations, it is apparent that the mound is decaying and that the leakage has been mitigated (Figure 2-11). Appendix D presents a detailed discussion of the aquifer response in 100-HR-3. Appendix E presents hydrographs for 100-D Area wells.

2.3.2 Numerical Modeling and Field Validation of Zone of Influence

A summary of the numerical modeling results supporting the 100-HR-3 pump-and-treat system in the 100-D Area is as follows:

- The hexavalent chromium pump-and-treat plume (from the D and DR Reactors, north to the Columbia River) is within the capture zone of the existing extraction well network, as shown in Figure 2-12.
- A portion of the hexavalent chromium plume north of the 182-D reservoir is located outside the capture zone of the existing extraction well network (Figure 2-12). This portion of the plume is not intercepted by the existing ISRM treatment zone. The DR-5 treatment system has been installed to capture this segment of the plume. A detailed discussion of the numerical model is presented in Appendix F. Table 2-1 presents a comparison of the measured and modeled water table elevations, as well as the average flow rates used in the numerical model.
- Figure 2-12 shows time markers spaced 1 year apart on the flow lines, based on the high November steady-state velocities. The fastest flow lines run from the new injection well, 199-D5-42, to near extraction well 199-5-32, which takes slightly more than 1 year of time for a pore velocity of about 2.2 m/day (800 m/365 days). The slower velocities are less than 1 m/day. This time-velocity snapshot in November is expected to have the largest velocities during the year. The effective porosity was set to a low value of 0.1, which also increases the calculated pore velocities.

2.3.3 Contaminant Monitoring in the 100-D Area

This section summarizes and interprets the analytical results obtained from groundwater wells and aquifer sampling tubes included in the interim remedial action and OU monitoring programs in the 100-D Area. *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1997b) and *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY04. The results presented below are the average annual concentrations for CY04, unless otherwise specified. Data are stored in the Hanford Environmental Information System (HEIS) database.

The principal contaminant of concern (COC) in the 100-D Area is hexavalent chromium. The RAO for reduction of chromium concentration is 22 μg/L at the compliance wells. Strontium-90, tritium, and nitrate are co-contaminants that are actively monitored but are not present in concentrations that exceed ecological risk criteria. In addition, sulfate is a contaminant of interest because it exceeds secondary drinking water standards in a limited number of wells. Institutional controls, implemented to satisfy an RAO, limit human exposure to hexavalent chromium and the co-contaminants.

Section 2.3.3.1 discusses the results of chromium monitoring, and Section 2.3.3.2 discusses the results of co-contaminant monitoring. The discussion of sampling results for the sections presented below exclude the results from those wells within and downgradient of the ISRM barrier. The locations of the monitoring wells and aquifer sampling tubes are shown in Figure 2-2.

The CY04 highlights, using only filtered hexavalent chromium data, are as follows:

- For 2004, average chromium concentrations decreased or were stable in three of four extraction wells and two compliance wells when compared to 2003 average concentrations; however, concentrations continued to remain above the RAO in both the extraction and compliance wells. Average chromium concentrations in CY04 decreased in extraction well 199-D8-54A to 47 μg/L. This was the largest decline in an extraction well for CY04 and represented a 65% decline from the average 2003 concentration of 134.7 μg/L. The largest average chromium concentration in a compliance well was 110.1 μg/L in well 199-D8-70.
- Four of the monitoring wells sampled in CY04 had increasing chromium concentrations. The largest percentage change (120%) was observed in well 199-D5-41, which increased from 976 μg/L in CY03 to 2,150 μg/L.
- Strontium-90 and tritium concentrations were less than the maximum contaminant levels (MCLs) in all 100-D Area samples collected during CY04.

2.3.3.1 100-D Area Chromium Monitoring Results

Chromium decreased in three of four extraction wells, with the largest decrease occurring in well 199-D8-54A. The compliance wells and extraction well 199-D8-72 remained stable for 2004, comparable to the findings reported in 2003 (see table below):

Well	Type	2003[a] Cr (µg/L)	2004[a] Cr (µg/L)	Percent Change[b]
199-D8-53	Extraction	124	76	-38
199-D8-54A	Extraction	134.7[a]	47	-65
199-D8-68	Extraction	118.7	84.5[a]	-29
199-D8-69	Compliance	69.5	69.5	0
199-D8-70	Compliance	125.6	110.1	-12
199-D8-72	Extraction	533	492.7	-8

[a] Average value.
[b] Percent change = (2003 - 2004) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

Chromium concentrations continued to increase significantly northwest of D Reactor and north of the 182-D reservoir. This area includes the wells presented in the table below, which, with the exception of well 199-D5-44, are located within the high-concentration portion of the northern chromium plume (Figure 2-9). The increase in chromium concentrations in well 199-D5-44, while small, represents a change from an historic trend of nondetectable values. The remaining monitoring wells all had stable to decreasing chromium values when comparing 2004 and 2003 results. The following table presents data for those wells in which chromium concentrations increased more than 20% in CY04 (changes less than 20% are considered stable):

Well	Type	2003[a] Cr (µg/L)	2004[a] Cr (µg/L)	Percent Change[b]
199-D5-15	Monitoring	281.5	559	+99
199-D5-20[c]	Monitoring/ Extraction	846	1,380[d]	+63
199-D5-41	Monitoring	976	2,150	+120
199-D5-44	Monitoring	4.4(U)	8	+82

[a] Average value.
[b] Percent change = (2003 - 2004) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
[c] Monitoring well converted to extraction well in July 2004.
[d] Value prior to conversion to an extraction well.
(U) = below quantitation limit

Figure 2-9 displays the fall 2004 100-D Area chromium plume generated from samples collected in November and December 2004. The values displayed include filtered total chromium and hexavalent chromium concentrations.

Aquifer sampling tubes located downgradient of the 100-D pump-and-treat system were sampled during March and November 2004. The highest hexavalent chromium values were measured at the aquifer tubes Redox 3-3.3 (223 µg/L) and Redox 3-3.4 (233 µg/L). Aquifer tubes DD-43-3 and DD-44-3 were also above 200 µg/L, with concentrations measured at 206.7 and 222 µg/L, respectively.

In comparison to samples collected at locations in 2003, only aquifer sampling tube DD-17-2 had an increased concentration, while sampling tubes DD-06-03, DD-10-4, and DD-15-3 all had decreasing hexavalent chromium concentrations.

2.3.3.2 100-D Area Co-Contaminant Monitoring Results

The 100-D Area co-contaminants are strontium-90, tritium, and nitrate (DOE-RL 1997b). Sulfate is a constituent of interest.

- None of the samples collected during 2004 or 2003 contained strontium-90 above the 8 pCi/L MCL. The highest 2004 average stronitium-90 concentration was 5 pCi/L in extraction well 199-D8-53.
- None of the samples collected in 2004 contained tritium above the 20,000 pCi/L MCL and, when compared to CY03 values, were either stable or decreasing. The highest 2004 average tritium concentration was 15,000 pCi/L in monitoring well 199-D5-18.
- The highest concentrations of nitrate were detected in samples located around the D and DR Reactors, and south and west of the 182-D reservoir. Nitrate was detected above the 45 mg/L MCL in 11 of 31 wells during 2004. The highest 2004 average nitrate concentration was 70.8 mg/L in well 199-D5-16.
- Sulfate was not detected at or above the 250 mg/L secondary MCL in any of the 29 wells sampled during 2004. The maximum concentration detected during 2004 sampling was 166 mg/L in well 199-D4-22. Sulfate above the 250 mg/L MCL was measured in aquifer tubes D-39-2 and D-41-2, located downgradient of the ISRM barrier.

Appendix G presents sample results for CY04 as well as a historical summary of contaminant and co-contaminant monitoring results for wells and aquifer tubes. Associated contaminant trend charts are presented in Appendix H.

2.4 AQUIFER RESPONSE IN THE 100-H AREA

2.4.1 Hydrogeologic Conditions at the 100-H Area

The hydrogeologic conditions in the 100-H Area are summarized below:

- The most prevalent groundwater flow direction is northeast, as shown in Figure 2-13. During the spring months, the river elevation is generally higher due to increased run-off and to provide more irrigation water and aid fish migration. This creates a near-shore short-term groundwater flow reversal from northeast to southwest that clearly shown in Figure 2-14, where the mid-April, May, and June 2004 river elevations are higher than near-river wells.
- The maximum river stage was 0.152 m lower in FY04 than in FY03; similarly, the minimum Columbia River stage was 0.178 m lower in FY04. Overall, the average Columbia River stage was 0.084 m lower in FY04 than in FY03.
- The maximum hydraulic gradient in the 100-H Area was 0.003 toward the northeast and the average hydraulic gradient is 0.002.
- The net groundwater flow velocity for 2004 over the 100-H Area was 0.006 m/day based on a hydraulic conductivity of 15.2 m/day and a porosity of 0.2. The hydraulic gradient was derived from a three-point solution of hourly water-level data from wells 199-H5-1A, 199-H4-10, and 199-H4-63.

- The average 2004 extraction well pumping rates ranged from 28.4 L/min in well 199-H4-12A to 91.6 L/min in well 199-H4-12A. This compares to a range of 32.2 to 107.5 L/min in 2003 and 41.6 to 88.6 L/min in 2002. Appendix D presents a detailed discussion of aquifer response at 100-HR-3. Appendix E presents hydrographs for 100-H Area wells.

2.4.2 Numerical Modeling

A summary of the numerical modeling results supporting the 100-HR-3 pump-and-treat system in the 100-H Area follows:

- The original 100-H hexavalent chromium pump-and-treat plume has been greatly reduced in area. Most of the remainder of the plume is within the capture zone of the existing extraction well network, as shown in Figure 2-15.
- The model shows an apparent gap in the capture zone between extraction wells 199-H4-12A and 199-H4-11 (Figure 2-15). This gap is largely because of insufficient saturated Hanford formation thickness in the area of extraction well 199-H4-65. This situation results in low flow rates and discontinuous operation of the well. Extraction well 199-H4-65 was modeled with a zero extraction rate because it was down during most of the second half of 2004. A detailed discussion of the numerical model is presented in Appendix F. Table 2-1 presents a comparison of the measured and modeled water table elevations, and the average flow rates used in the numerical model.

  Figure 2-15 shows time markers spaced 180 days apart on the flow lines, based on the high November steady-state velocities. The fastest flow lines are the high conductivity region in the southernmost part of Figure 2-15, where the pore velocities are as high as 6 m/day (1,100 m/180 days) from injection well 199-H3-5 to past monitoring well 199-H6-1. The pore velocities are as low as 1.7 m/day (approximately 300 m/180 days) upgradient from extraction well 199-H4-11. The November velocities are expected to be the highest velocities during the year. The effective porosity was set to a low value of 0.1, which also increases the calculated pore velocities.

2.4.3 Contaminant Monitoring in the 100-H Area

This section summarizes and interprets the analytical results obtained from groundwater monitoring wells and aquifer sampling tubes supporting the 100-H Area pump-and-treat remedial action and the 100-HR-3 OU monitoring program. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE-RL 1997b) and the *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY04. The results presented below are the average annual concentrations for CY04, unless otherwise specified. Section 2.4.3.1 includes a discussion of chromium monitoring results. The RAO for chromium concentrations is 22 μg/L at the compliance wells. Section 2.4.3.2 includes a discussion of the monitoring results for the remedial action co-contaminants strontium-90, tritium, nitrate, technetium-99, and uranium.

The CY04 highlights are as follows:

- The 2004 average chromium concentrations were below the RAO of 22 μg/L in all but two extraction wells. Decreases in chromium were observed in extraction wells 199-H4-7, 199-H4-11, 199-H4-12A, and 199-H4-15A when compared to CY03 sampling results.

- Chromium concentrations remained above the RAO of 22 μg/L in all four of the compliance wells. The maximum 2004 compliance well average chromium concentration was 55.1 μg/L in well 199-H4-5. Other compliance well concentrations ranged from 43.7 to 54.7 μg/L chromium.
- The highest chromium concentrations were again downgradient of the former 183-H solar evaporation basins at monitoring well 199-H4-3. The average concentration for this well was 65 μg/L in CY04 compared to 75 μg/L in CY03.
- Fewer well samples were characterized by co-contaminant concentrations that were above MCLs compared to 2003.

2.4.3.1 100-H Area Chromium Monitoring Results

Chromium trends in CY04 were stable to decreasing in four of five extraction wells. Extraction well 199-H4-7 had the largest percent change, followed by wells 199-H4-11, 199-H4-12A, and 199-H4-15A. Extraction wells 199-H4-12A and 199-H4-15A exceeded the RAO with an average annual chromium concentration of 39 μg/L and 40 μg/L, respectively. Well 199-H3-2A was the only extraction well that did not show a significant change in concentration. The four compliance wells were all stable for CY04. Decreases in chromium concentrations were observed at seven monitoring wells in CY04. Chromium concentrations generally remained stable for the remaining monitoring wells located within the plume, while wells outside the plume continue to display decreasing concentration. Figure 2-13 illustrates the 100-H chromium plume and associated historical chromium trends for 2004. The table below summarizes the changes in chromium concentrations from 2003 to 2004 in 100-H extraction wells, compliance wells, and monitoring wells with chromium above 22 μg/L or changes greater than 20%:

Well	Type	2003[a] Cr (μg/L)	2004[a] Cr (μg/L)	Percent Change[b]
199-H4-7	Extraction	33.2	15	-55
199-H4-11	Extraction	33	21.5	-35
199-H4-12A	Extraction	54.9	39	-29
199-H4-15A	Extraction	56.3	40	-29
199-H4-4	Compliance	37.1	43.7	18
199-H4-5	Compliance	67.2	55.1	-18
199-H4-63	Compliance	45.2	48.7	-8
199-H4-64	Compliance	51.9	54.7	+5
199-H4-12B	Monitoring	56.3	55.4	-2
199-H4-14	Monitoring	64.8	39.8	-39
199-H4-3	Monitoring	70	65	-7
199-H4-8	Monitoring	26.5	16	-40
199-H4-13	Monitoring	21.5	23	-7
199-H4-15B	Monitoring	40	36	-10
199-H4-15CS	Monitoring	107	87	-19
199-H4-16	Monitoring	9.5	6	-37
199-H4-17	Monitoring	22	22	0

Well	Type	2003[a] Cr (µg/L)	2004[a] Cr (µg/L)	Percent Change[b]
199-H4-18	Monitoring	19.5	13	-33
199-H4-46	Monitoring	12	8	-33
199-H4-48	Monitoring	11	6.49	-41
199-H4-49	Monitoring	9	6.5	-28

[a] Average concentration.
[b] (2004 - 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

The CY04 results include filtered, total chromium, and hexavalent chromium concentrations.

Aquifer tubes were sampled downgradient of the 100-H pump-and-treat system during March and November 2004. Aquifer sampling tubes 51-D and 51-M, located south of the 100-H Area, had the highest measured values of hexavalent chromium at 48.2 and 40.5 µg/L, respectively.

In comparison to results from CY03, only aquifer tube 50-S showed an increasing trend in chromium concentration. Tubes 47-D, 49-S, and 50-M had decreasing concentrations of hexavalent chromium, while hexavalent chromium concentrations in aquifer tubes 48-M, 48-S, 49-M, and 50-S remained stable.

2.4.3.2 100-H Area Co-Contaminant Monitoring Results

The 100-H Area co-contaminants are strontium-90, technetium-99, uranium, tritium, and nitrate (DOE-RL 1997b). Further discussion on these co-contaminants is provided below:

- **Strontium-90:** Two wells sampled in 2004 were above the 8 pCi/L MCL; in 2002, five wells were above the 8 pCi/L MCL. The two wells above the strontium-90 MCL (results presented in the table below) are located downgradient of the former 107-H retention basin and the former 116-H-1 liquid waste disposal trench. Both of these facilities were excavated in 1999 through 2000 and were backfilled in 2001. The remaining wells had stable to decreasing values of strontium-90. None of the aquifer tubes measured for strontium-90 exceeded the 8 pCi/L MCL.

Well	Type	2003[a] Sr-90 (pCi/L)	2004[a] Sr-90 (pCi/L)	Percent Change[b]
199-H4-63	Compliance	24.6	38.8	+58
199-H6-11	Monitoring	25.6	15	-41.3

[a] Average concentration.
[b] (2004 – 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

- **Technetium-99:** All wells and aquifer tubes sampled in CY04 were below the 900 pCi/L MCL. The highest concentration of technetium-99 was measured in well 199-H4-3, with an average concentration of 694 pCi/L, which represents a significant increase from the 48 pCi/L reported in CY03. Well 199-H4-4 had an increase from 65.5 pCi/L in CY03 to 200 pCi/L in CY04. In 2002, well 199-H4-9 contained technetium-99 at 986 pCi/L, which is the only time the well was above the MCL. The 2003 sample result for this well was 169 pCi/L of technetium-99 and has increased to 315 pCi/L in 2004.

- **Uranium:** With the exception of well 199-H4-3, all wells sampled in 2004 were below the 30 µg/L MCL. Monitoring well 199-H4-3, which is located downgradient of the former 183-H solar evaporation basins, was characterized by 93.5 µg/L total uranium in 2004, an increase from the 54.3 µg/L in 2003.
- **Tritium:** All wells analyzed for tritium in CY04 were below the 20,000 pCi/L MCL. The highest average tritium concentration was 5,160 pCi/L in well 699-97-43, which is upgradient of the 100-H Area. Compliance well 199-H4-63 yielded a concentration of 1,630 pCi/L in 2004, which is an increase from the 388 pCi/L reported in 2003. All remaining wells displayed stable to decreasing concentrations for the year.
- **Nitrate:** Of the wells sampled for nitrate in 2004, three results were above the 45 mg/L MCL. Wells exceeding the MCL are located downgradient of the former 183-H solar evaporation basins, which is a possible source; however, nitrate is a widespread contaminant in the 100 Area. The table below summarizes nitrate concentrations in 100-H wells that are above the 45 mg/L MCL:

Well	Type	2003[a] NO_3 (mg/L)	2004[a] NO_3 (mg/L)	Percent Change[b]
199-H4-3	Monitoring	192	240	+25
199-H4-4	Compliance	35	92	+163
199-H4-9	Monitoring	112	130	+16

[a] Average concentration.
[b] (2004 – 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

Appendix G presents a historical summary of contaminant and co-contaminant monitoring results for wells and aquifer tubes. Associated contaminant trend charts are presented in Appendix H.

2.5 QUALITY CONTROL RESULTS FOR 100-D AND 100-H MONITORING DATA

The QC results for the 100-HR-3 sampling activities involve field or offsite laboratory testing for hexavalent chromium or total chromium.

The highlights of QC data for CY04 100-D and 100-H Area sampling are summarized below. Tables listing the complete QC results are found in Appendix I.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent of Pairs <20% RPD
Field replicates (hexavalent chromium)	34	34	100%
Field/offsite laboratory splits (hexavalent chromium)	28	24	86%
Offsite laboratory replicates (total chromium)	13	12	92%
Offsite laboratory splits (total chromium)	12	12	100%

RPD = relative percent difference

The U.S. Environmental Protection Agency's (EPA's) *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA 1988) for field-tested replicates is ±20%. All field replicates were within acceptable limits. There are no functional guidelines for split results or offsite laboratory replicates, but the results correlated well based on the relative percent differences (RPDs).

2.6 CONCLUSIONS

The pump-and-treat system continues to make significant progress toward remediating the contaminant plume along the 100-D and 100-H Area shorelines by extracting groundwater before it reaches the river. In addition, human receptors are protected onsite using institutional controls. Details regarding the operation of the existing pump-and-treat system will be useful in evaluating system upgrades and modifications.

- ***RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River. The RAO for compliance wells is 22 µg/L based on the 11 µg/L ambient water quality criterion in place at the time of the signing of the ROD and a 1:1 dilution ratio.***

  <u>100-D Area</u>:

  - Approximately 164 million L of groundwater were treated during CY04, and 30.1 kg of hexavalent chromium were removed using the 100-HR-3 and DR-5 pump-and-treat systems.
  - Chromium concentrations decreased or were stable from 2003 to 2004 in three of four 100-D Area extraction wells and remained stable in the two compliance wells. However, chromium concentrations were above the 22 µg/L RAO in all of the extraction and compliance wells.
  - Average hexavalent chromium concentrations of 1,380 µg/L were detected in filtered samples from well 199-D5-20 (which is now an extraction well for DR-5). This represents an increase of 63% from 2003. In addition, well 199-D5-41 was characterized by an average concentration of 2,150 µg/L chromium in 2004, a 120% increase from 2003.
  - Strontium-90 concentrations were less than the MCLs for all 100-D Area samples analyzed during CY04.
  - Average tritium concentrations were less than MCLs in all 100-D Area wells.

- Plume and water table surface maps indicate that the hydraulic barrier separating the northern plume contained by the pump-and-treat system and the southwest plume controlled by the ISRM is dissipating and the plumes appear to be merging.
- Monitoring wells installed near the 182-D reservoir have helped to better delineate the chromium plume and groundwater in this area. These wells were designed for potential use as extraction wells and can be converted to that function for the DR-5 pump-and-treat system as needed.
- With the addition of three new extraction wells, numerical modeling results indicate that the extraction well network is containing the majority of the central and northern portion of the 100-D chromium plume. This is the portion of the plume originally targeted by the interim action ROD (EPA et al. 1996). The southwest 100-D chromium plume is targeted by the ISRM barrier. Modeling indicates that except for a small portion of plume that by passes the barrier on the northwest end, the majority of the plume is captured by the ISRM. Planned expansion of the new DR-5 system includes additional extraction wells in the portion of the flow field that bypasses the northeastern end of the ISRM.

<u>100-H Area</u>:

- Approximately 153.5 million L of groundwater were treated in CY04, and 3.5 kg of hexavalent chromium were removed.
- The 2004 average chromium concentrations were below the RAO of 22 μg/L in all but two extraction wells. Chromium concentrations remained above the RAO of 22 μg/L in all four of the compliance wells. The maximum 2004 compliance well average chromium concentration was 55.1 μg/L in well 199-H4-5. Other compliance well concentrations ranged from 43.7 to 54.7 μg/L chromium.
- The highest average chromium concentrations were downgradient of the former 183-H solar evaporation basins, near monitoring well 199-H4-3, in which the average concentration was 65 μg/L.
- The average 2004 chromium concentration in extraction well 199-H3-2A was 9 μg/L. Concentrations in this well were more than 100 μg/L in 1997 when pump-and-treat operations began, but annual November values have been below the RAO cleanup goal for the past 5 years.
- The 2004 chromium concentrations in the other 100-H Area extraction wells ranged from 15 μg/L in well 199-H4-7 to 40 μg/L in well 199-H4-15A.
- Fewer well samples had co-contaminant concentrations that were above MCLs compared to November 2003.
- Numerical modeling results indicate that the extraction well network generally contains the plume along much of the 100-H Area shoreline. Gaps in capture are due largely to lowered pumping rates in some wells because of a thin, saturated aquifer and low water levels. To address these gaps, several compliance and monitoring wells were converted to extraction wells in January 2005.

- ***RAO #2: Protect human health by preventing exposure to contaminants in groundwater.***

  Results: The interim remedial action ROD establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances in each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents.

  The effectiveness of institutional controls was presented in the *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a). The findings of this report indicate that institutional controls were maintained to prevent public access, as required.

- ***RAO #3: Provide information that will lead to a final remedy.***

  In order for a pump-and-treat strategy to work for a final remedy at 100-D, identification and elimination of the continuing source of chromium is fundamental. If the source can be controlled, then the pump-and-treat system could be operated until the concentrations decline to meet the RAO as a final remedy (e.g., in the 100-H Area); if not, then a long-term solution other than pump-and-treat is needed. A permeable reactive barrier (e.g., ISRM) is one possible solution in the event that source control or removal is not possible. The ISRM was installed to provide both immediate treatment of a significant portion of the chromium plume and to provide performance data for evaluation of this approach as a final remedy. Events and new information generated during 2004 that bear on the above final remedy considerations are summarized as follows:

  <u>Source control/identification</u>:

  - Pressurized water lines were leak-tested, and critical sections of the distribution network near suspected source locations were cut and capped in the 100-D Area.
  - Renewed efforts to locate the source of hexavalent chromium in the suspected spill sites in the south-central 100-D Area were unsuccessful during CY04. Either residual soil column sources are deeper than the 4.6-m test pit excavation depth, or there are a few point sources that cannot be located with the investigation spacing used.

  <u>Evaluation of treatment options</u>:

  - Improved cost effectiveness of 100-HR-3 pump-and-treat system was demonstrated with data from the operation of a small, modular, self-contained treatment system (manufactured by MR3) and by employing an inlet sacrifice resin column to minimize the amount of resin that must be shipped to the ERDF. A more cost-effective pump-and-treat system is needed as part of a final remedy (if source control is successful), as well as to reduce the cost of current operations.

- Evaluation of ISRM performance issues intensified during the year. Two expert panel workshops sponsored by U.S. Department of Energy (DOE)-Headquarters were held in Richland, Washington, in April and May 2004. Final reports and recommendations generated from this effort led to plans to investigate mitigation measures for the northeastern end of the ISRM barrier where premature loss in reductive capacity is occurring. Initial characterization (July through August 2004) included determination of vertical velocity profiles in all of the 66 injection wells to determine the extent of suspected preferential flow (high-permeability zones) within the screened interval of the aquifer treatment zone. Recommendations were made for the application of amendments to treat high permeability zones that may have been inadequately treated with the dithionite injection protocol used for the ISRM. Laboratory and field testing to support implementation of the recommendations are planned for FY05 through FY06.
- Alternatives to the ISRM approach for installation of a permeable reactive barrier considered the emplacement of zerovalent iron by hydrofracture or air injection. A vendor cost proposal was solicited for a 2,000-ft barrier using the hydrofracture method. Permeable reactive barrier alternatives may be needed for a final remedy if the soil column sources cannot be located and fixed in place or removed.

2.7 RECOMMENDATIONS

<u>100-D Area:</u>

- Continue water-level monitoring near the 182-D reservoir (1) to determine the effects and magnitude of previous reservoir leakage and the new pump-and-treat system on the hydraulic flow regime, and (2) to measure the impact on the chromium plume extent and movement.
- Evaluate the cost and effectiveness of existing or new wells that could be used to close a capture zone gap between DR-5 and the ISRM barrier. Evaluate the cost and effectiveness for the expansion of the original 100-D and DR-5 pump-and-treat system to target high concentration areas for mass reduction.
- Define the edge of the chromium plume northeast of the original 100-D pump-and-treat system.
- Based upon the results of the 100-KR-4 calcium polysulfide treatability test, evaluate the cost and effectiveness for implementing a similar technology in the 100-D Area.
- Continue to cross-reference source area cleanup activities for integration into the final ROD.

<u>100-H Area:</u>

- Implement changes in extraction well and injection well locations to address plume gaps and focus treatment on higher concentration areas.
- Evaluate the cost and effectiveness of existing and new wells to target high concentration areas for mass reduction.
- Continue to cross-reference source area cleanup activities for integration into the final ROD.

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Figure 2-1. Location of the 100-HR-3 Operable Unit.

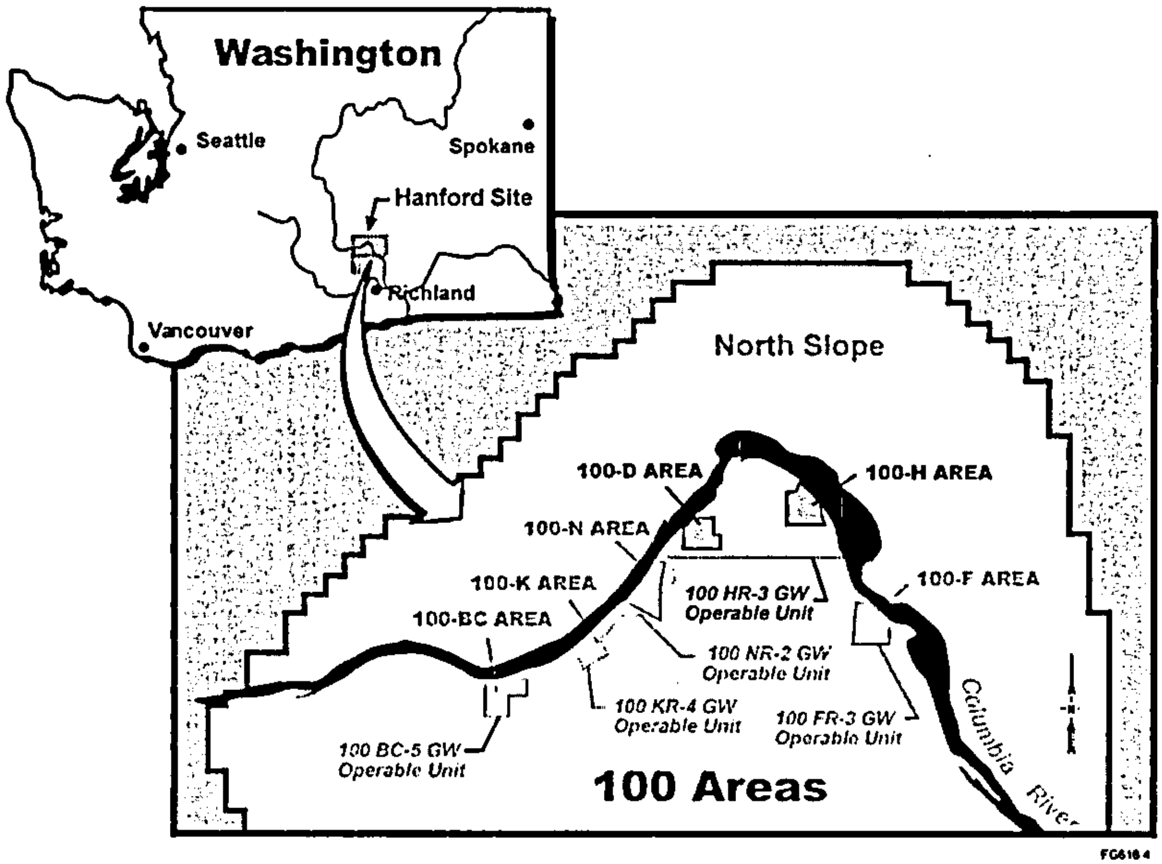


Figure 2-2. 100-HR-3 Operable Unit – 100-D Area Wells and Aquifer Sampling Tubes.

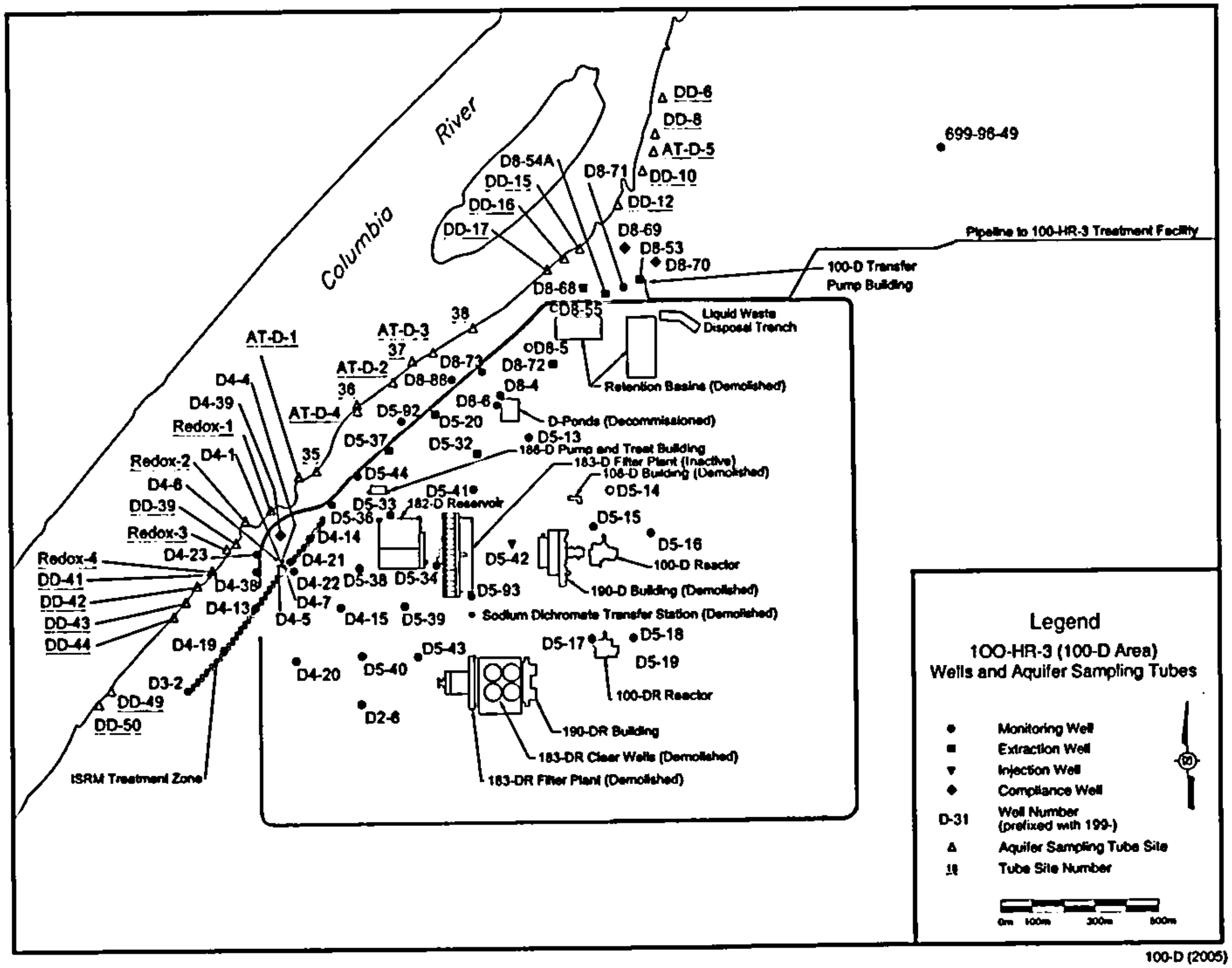


Figure 2-3. 100-HR-3 Operable Unit – 100-H Area Wells and Aquifer Sampling Tubes (as of December 2004)

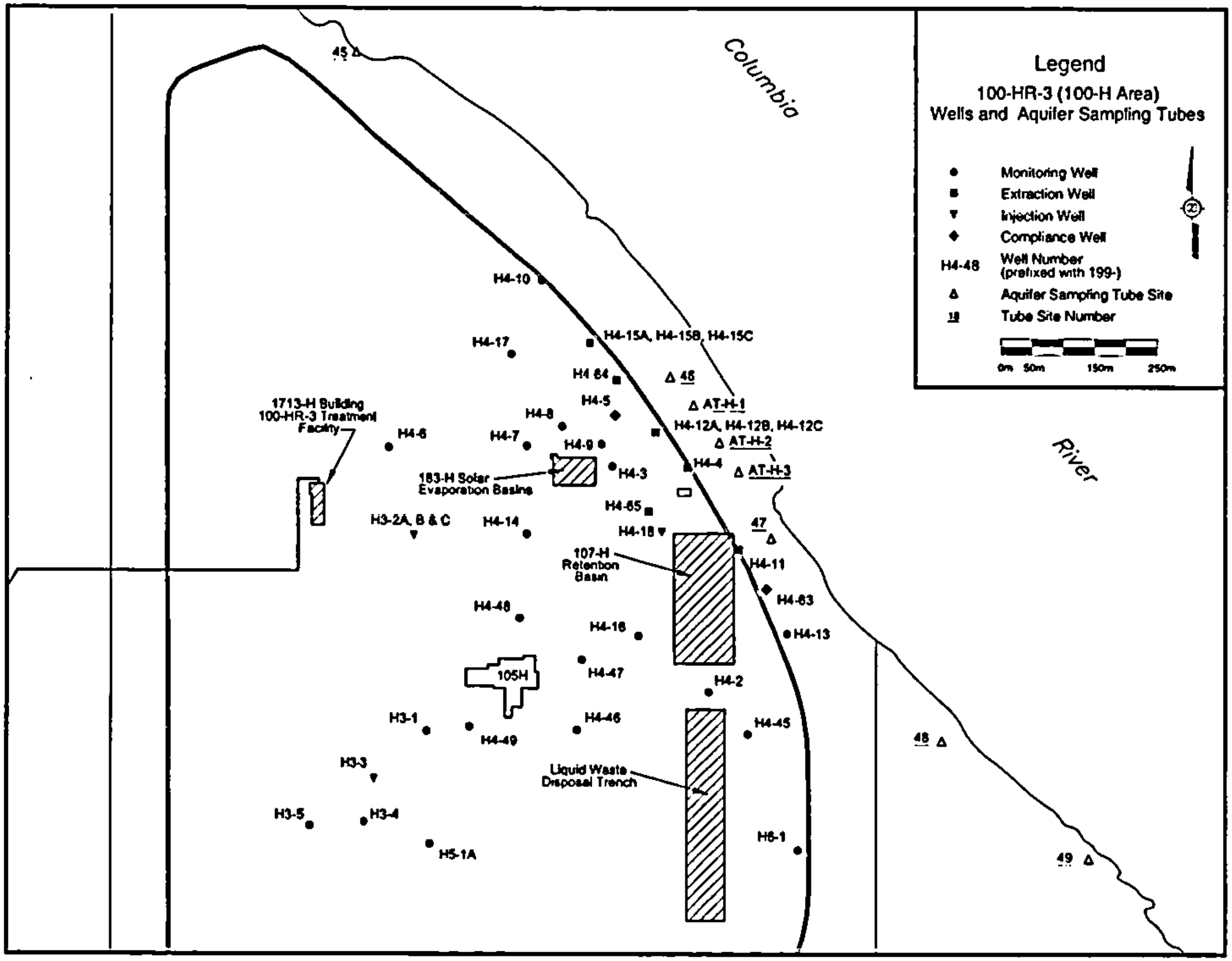


Figure 2-4. 100-HR-3 Pump-and-Treat System Schematic.

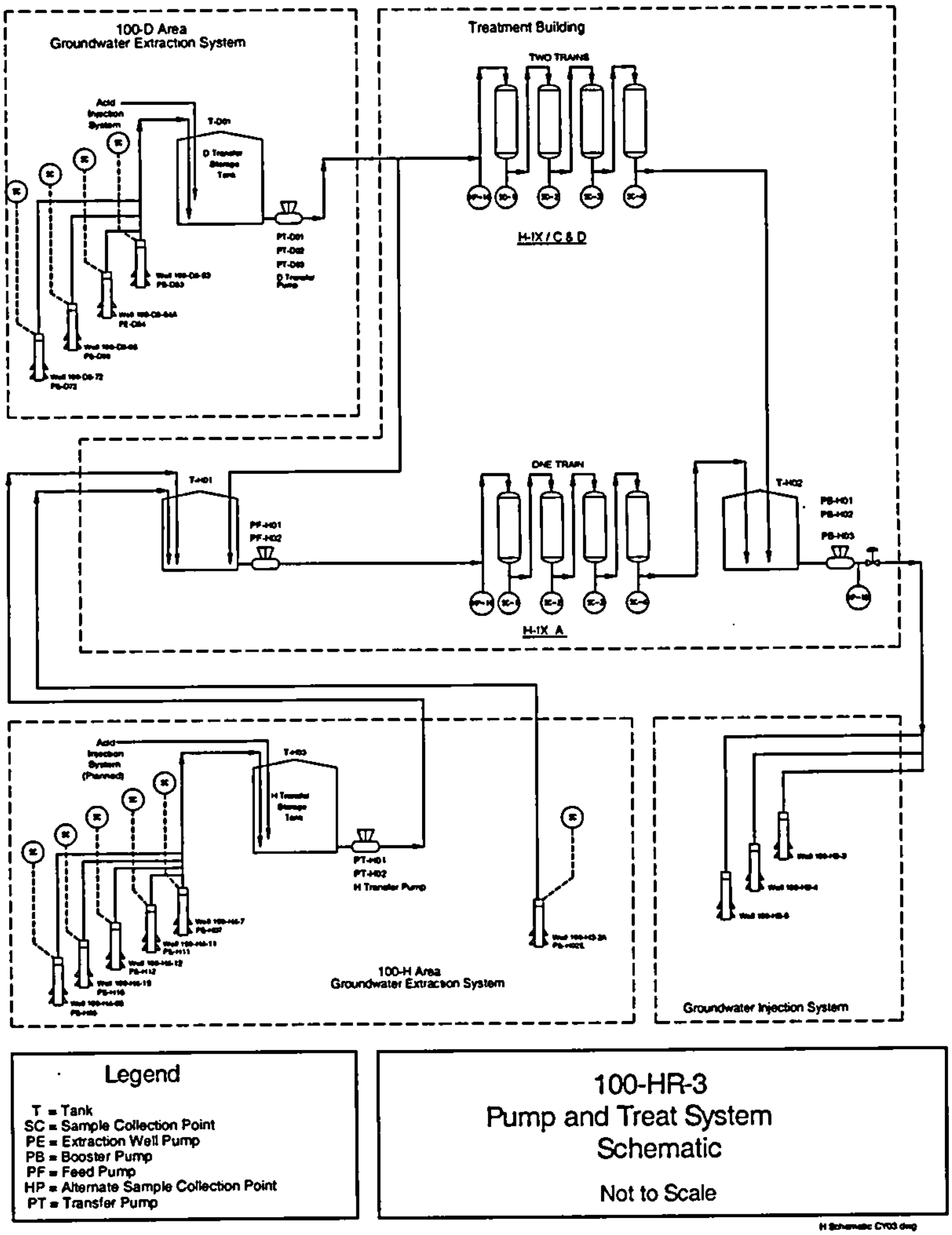


Figure 2-5. DR-5 Pump-and-Treat System Schematic.

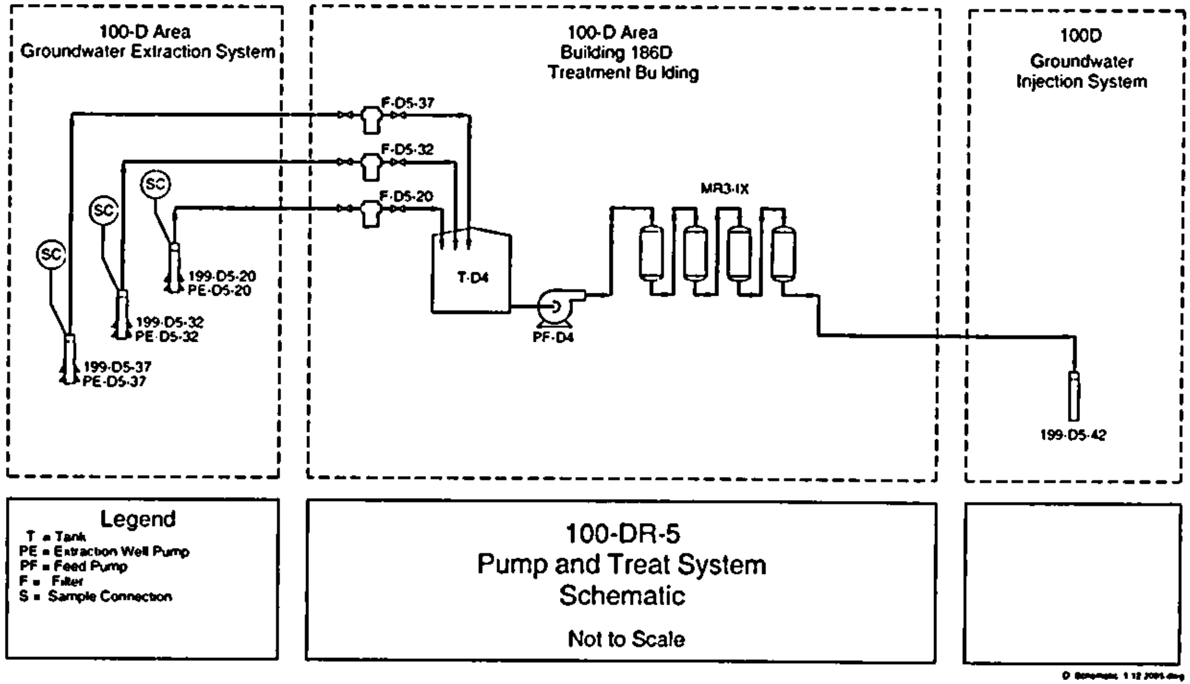
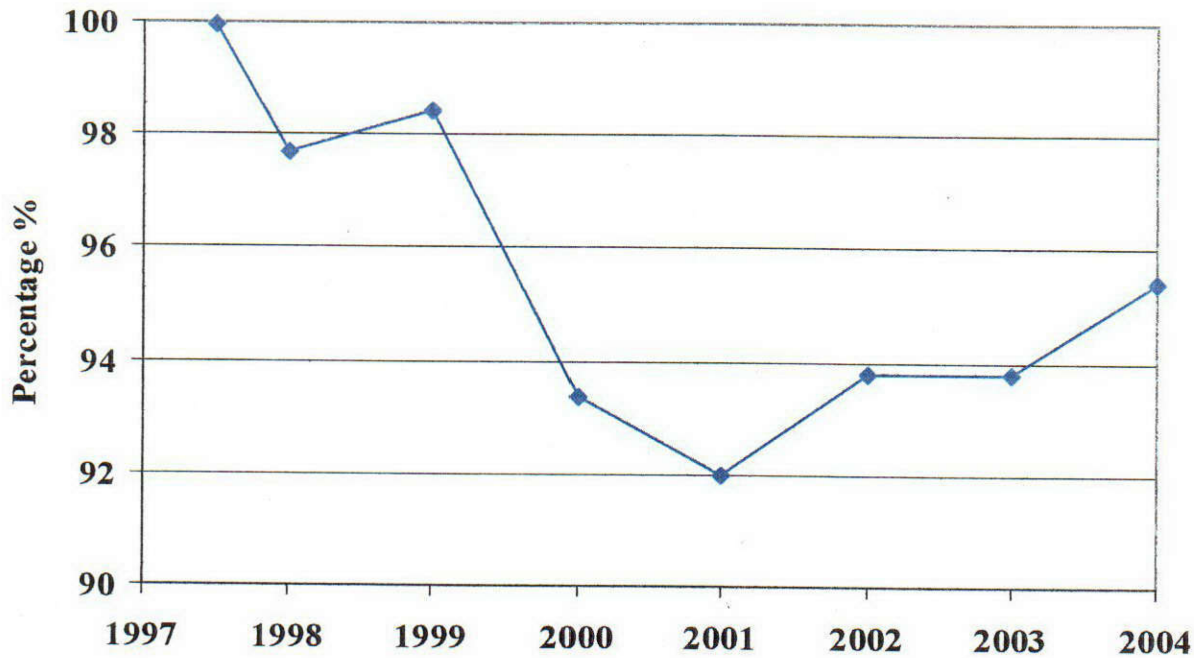


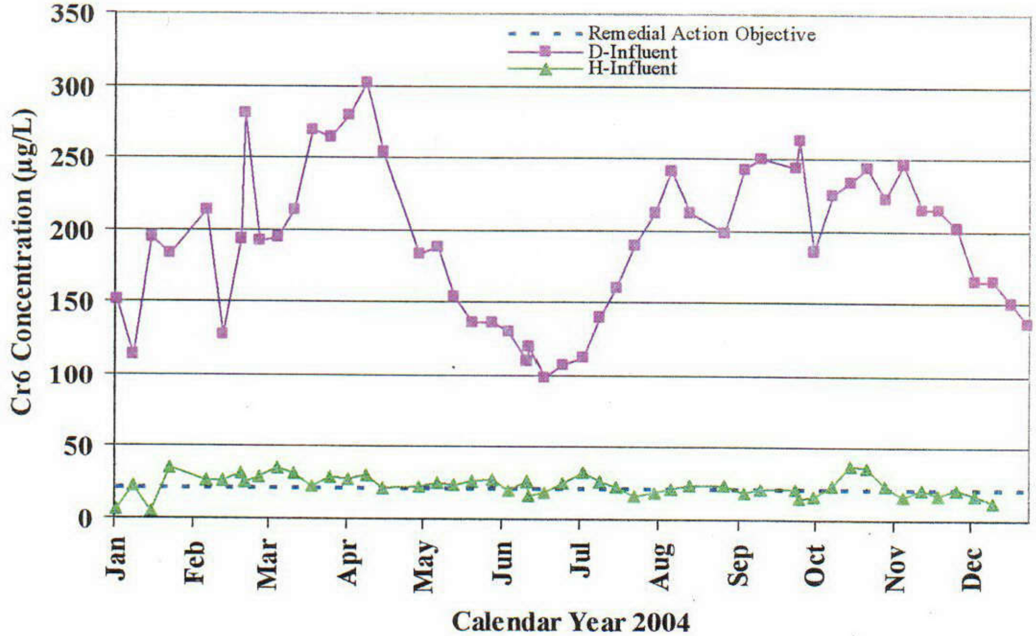
Figure 2-6. 100-HR-3 Pump-and-Treat Trends of Average Removal Efficiencies.[a]

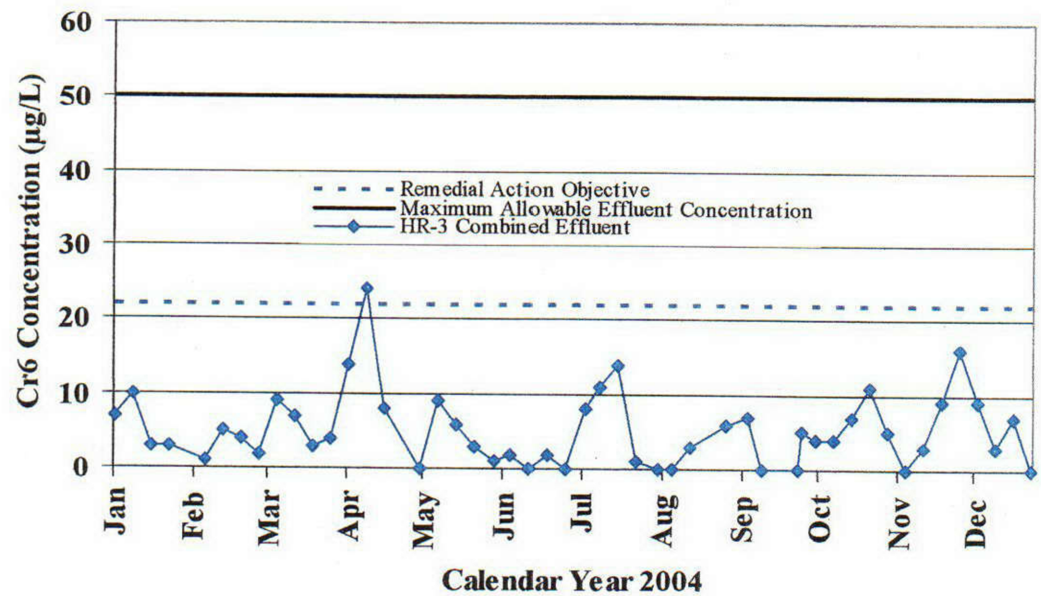


NOTE: The 100-HR-3 pump-and-treat trends of average removal efficiencies do not include the DR-5 pump-and-treat system.

[a] Average removal efficiency is calculated as: (% by mass) = [(influent – effluent) / influent].

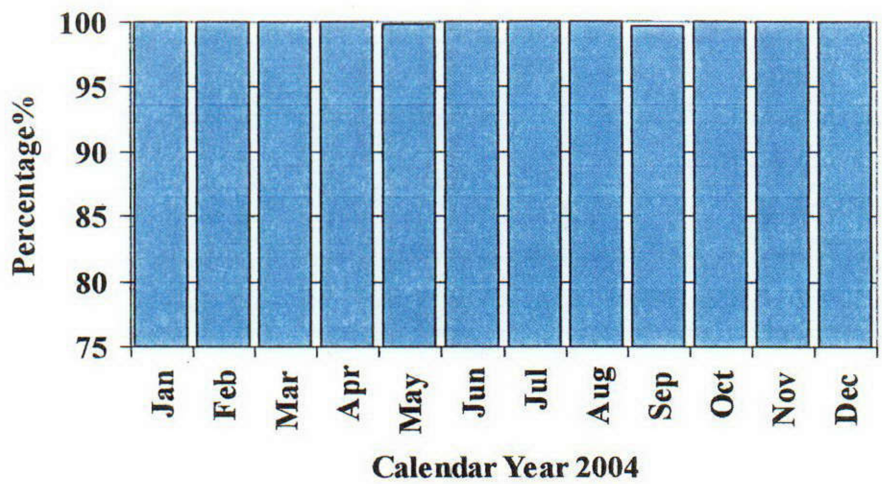
Figure 2-7. Calendar Year 2004 100-HR-3 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.





NOTE: Calendar year 2004 100-HR-3 pump-and-treat trends of influent and effluent hexavalent chromium concentrations do not include the DR-5 pump-and-treat system.

Figure 2-8. 100-HR-3 System Availability and On-Line Percentages for Calendar Year 2004.



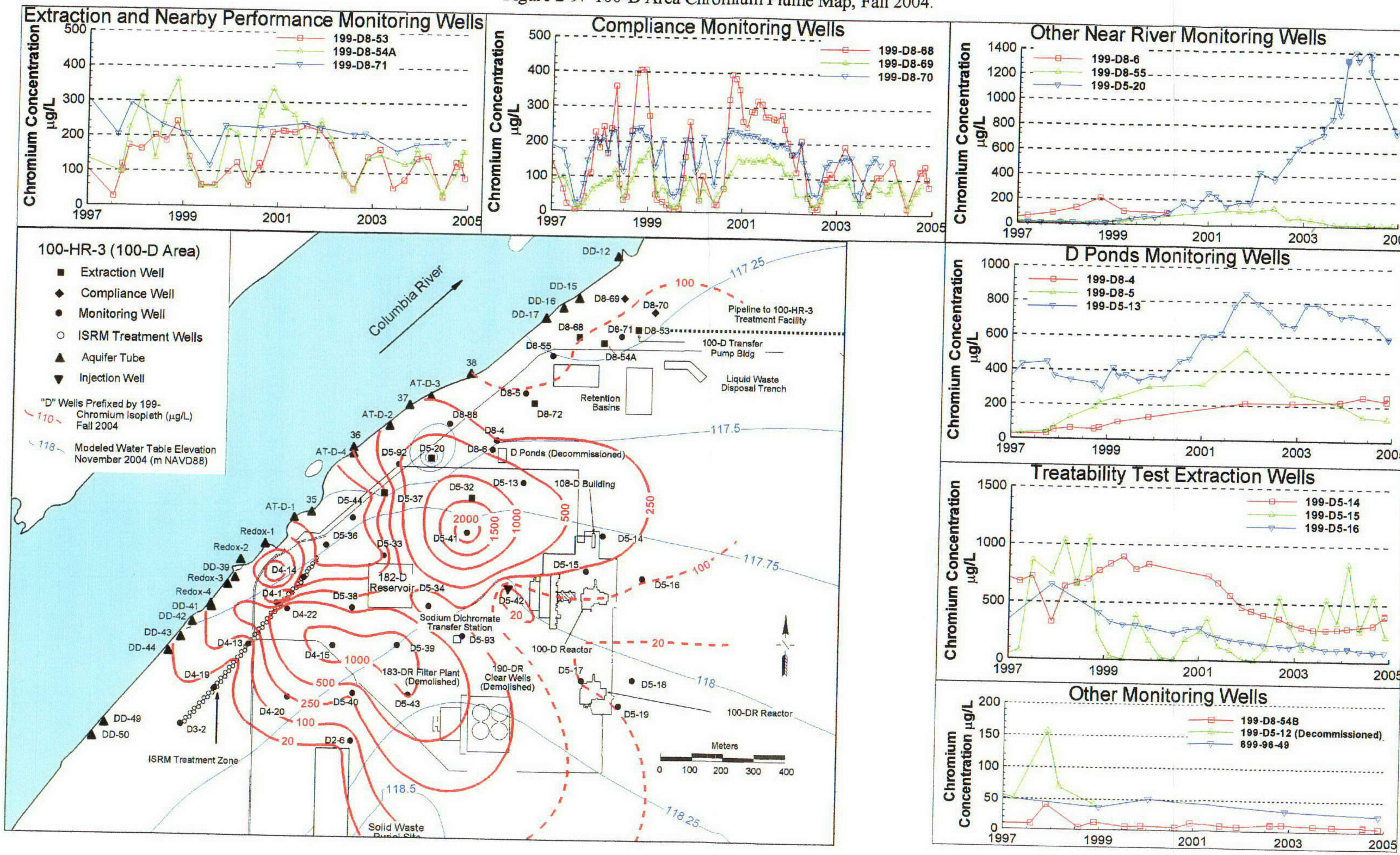
Summary of system availability:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	73
Planned operations (hours)	8,711
Unscheduled downtime (hours)	1
Total time on-line (hours)	8,710
Total availability (%)	99.1
Scheduled system availability (%)	99.9

Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].

Total availability[(total possible run-time – scheduled and unscheduled downtime) / total possible run-time)].

NOTE: The 100-HR-3 system availability and on-line percentages for calendar year 2004 do not include the DR-5 pump-and-treat system.

Figure 2-9. 100-D Area Chromium Plume Map, Fall 2004.



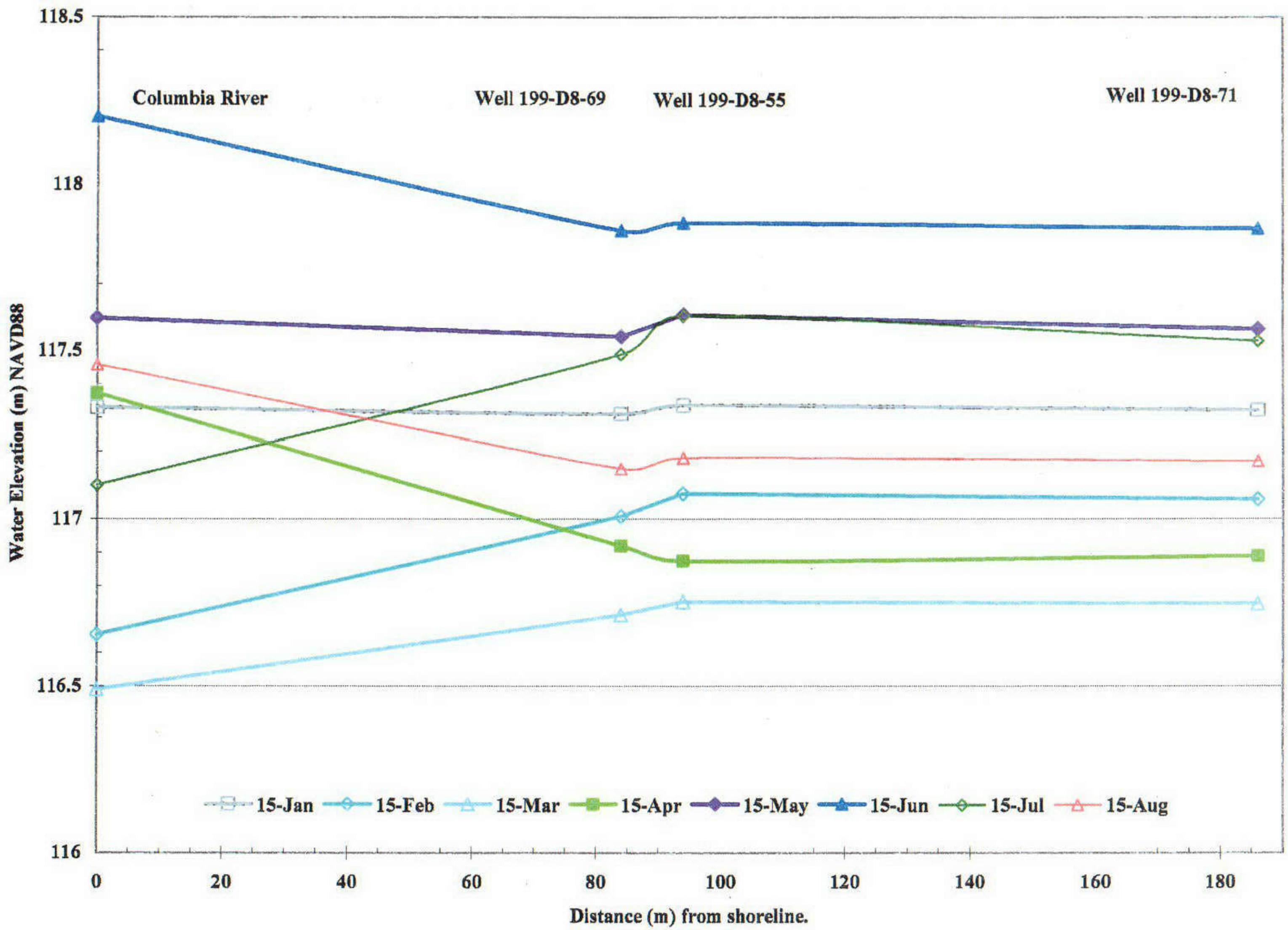


Figure 2-10. Water Elevation Versus Distance from the Columbia River in the 100-D Area Wells.

Figure 2-11. Decay of the Groundwater Mound Around the 182-D Reservoir, as Measured at Adjacent Monitoring Well 199-D5-33.

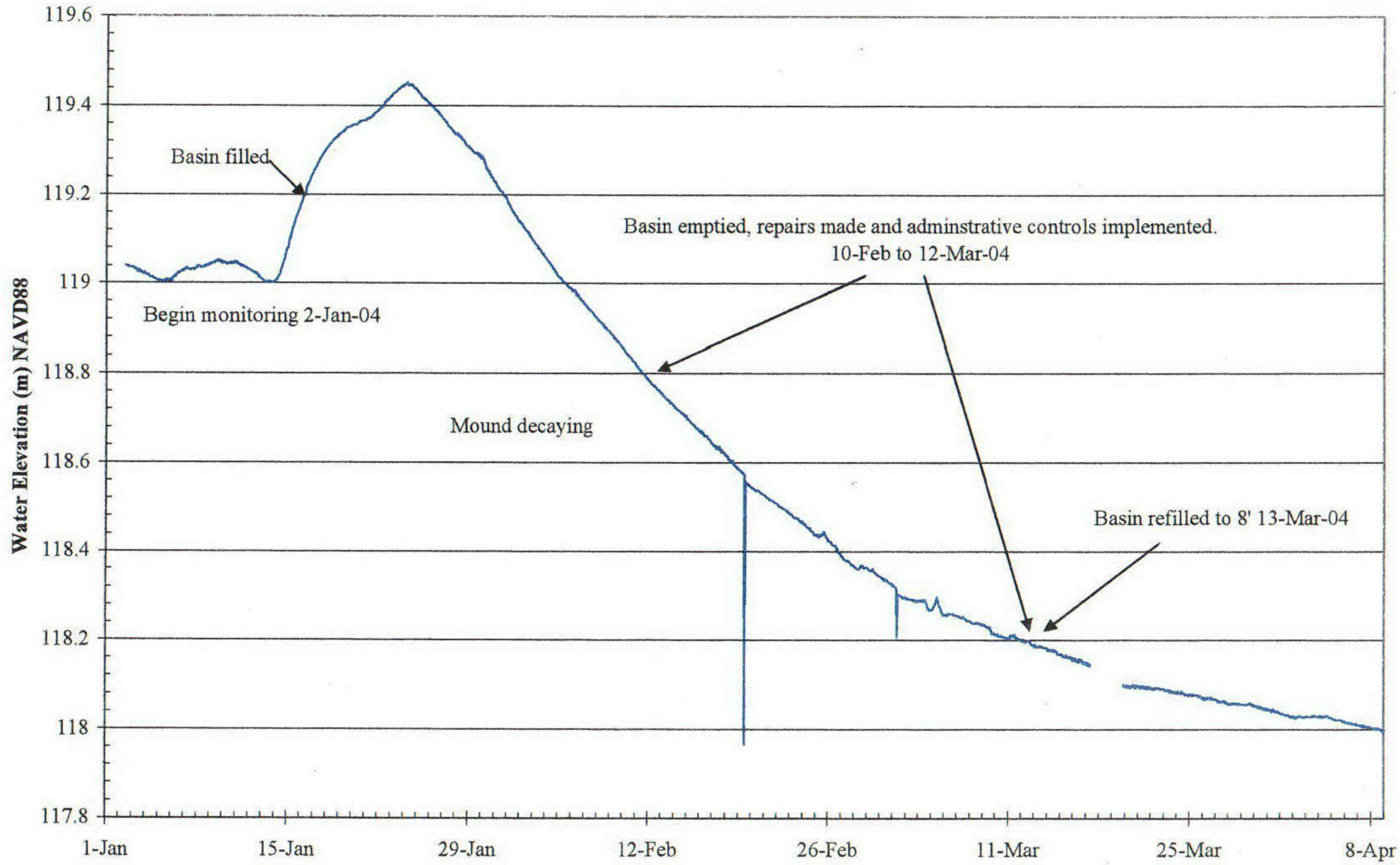


Figure 2-12. Estimated Steady-State Hydraulic Capture Zone Development by 100-HR-3 Operable Unit, 100-D Area Extraction Wells.

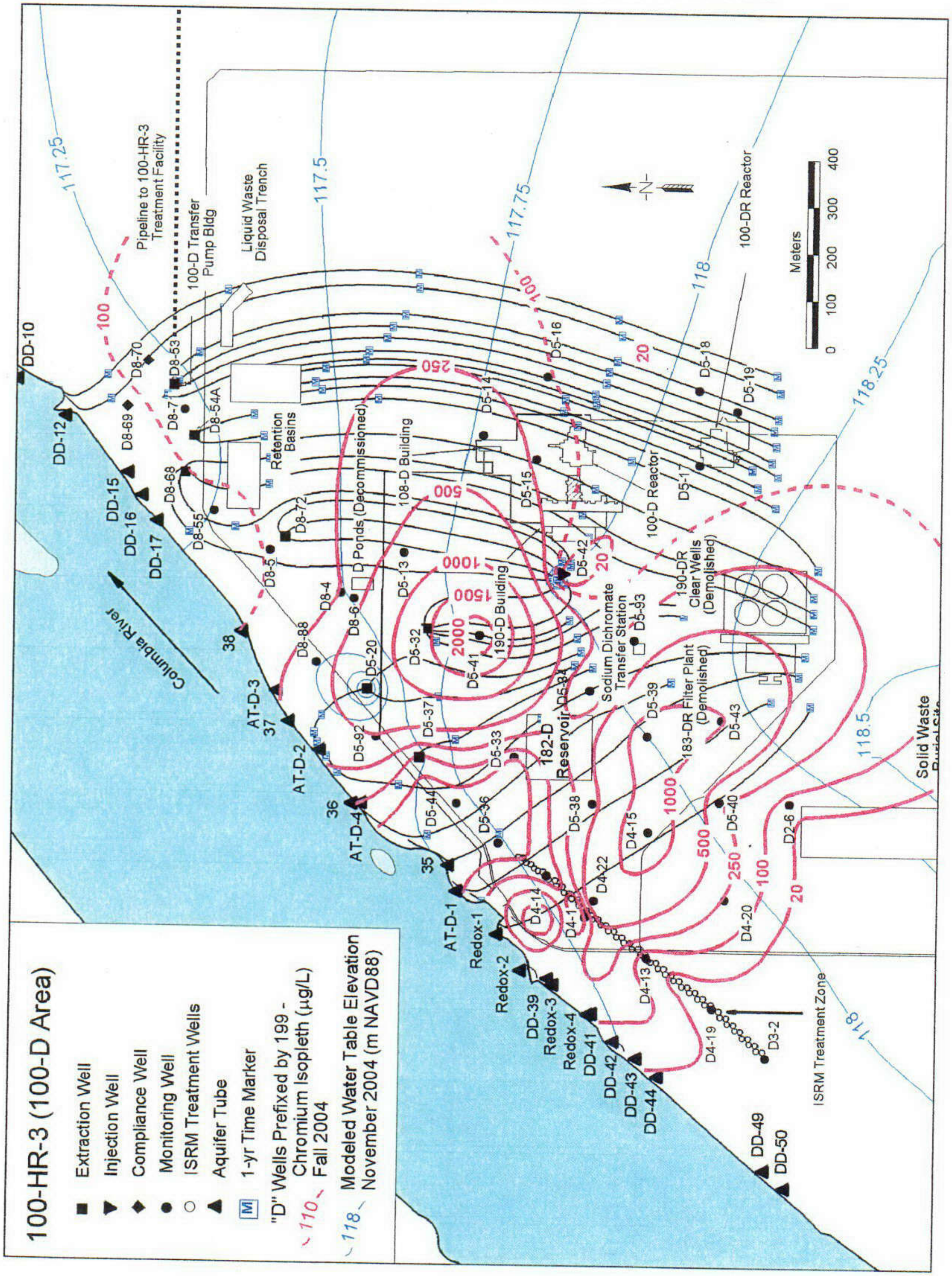


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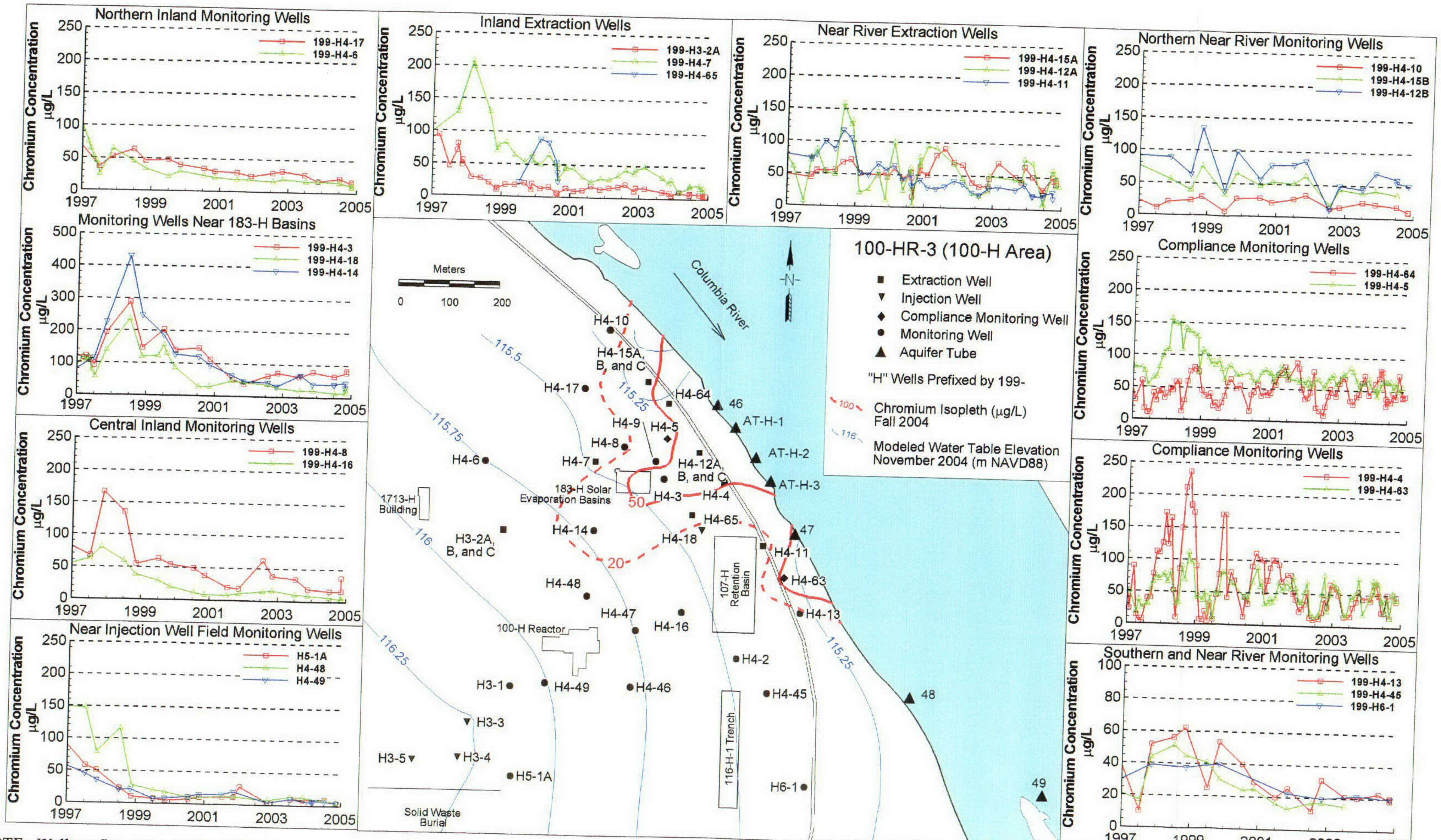
Figure 2-13. 100-H Area Chromium Plume, Fall 2004.



NOTE: Well configuration presented is prior to system reconfiguration in December 2004.

Figure 2-14. Water Elevation Versus Distance from the Columbia River in 100-H Area Wells.

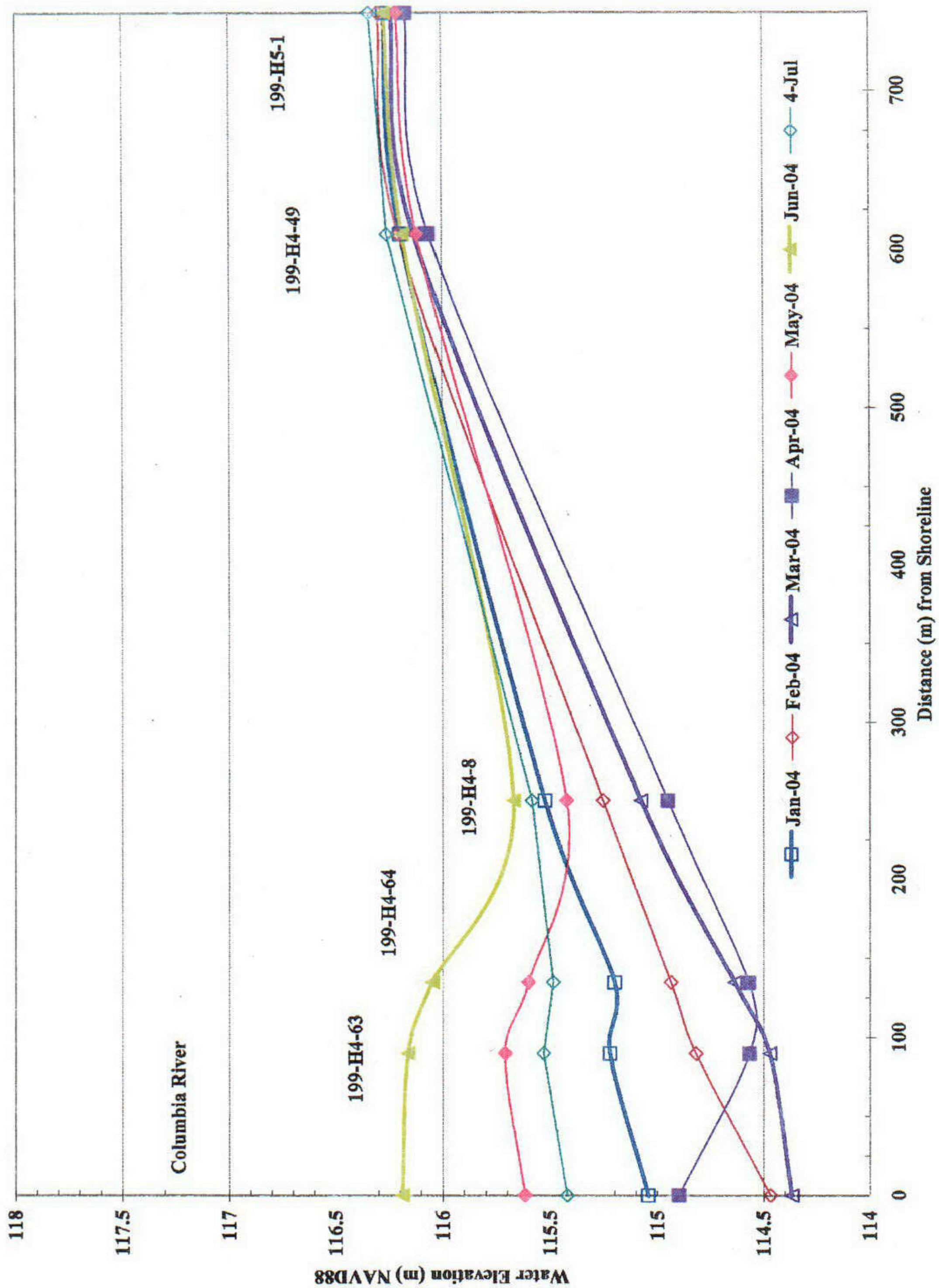
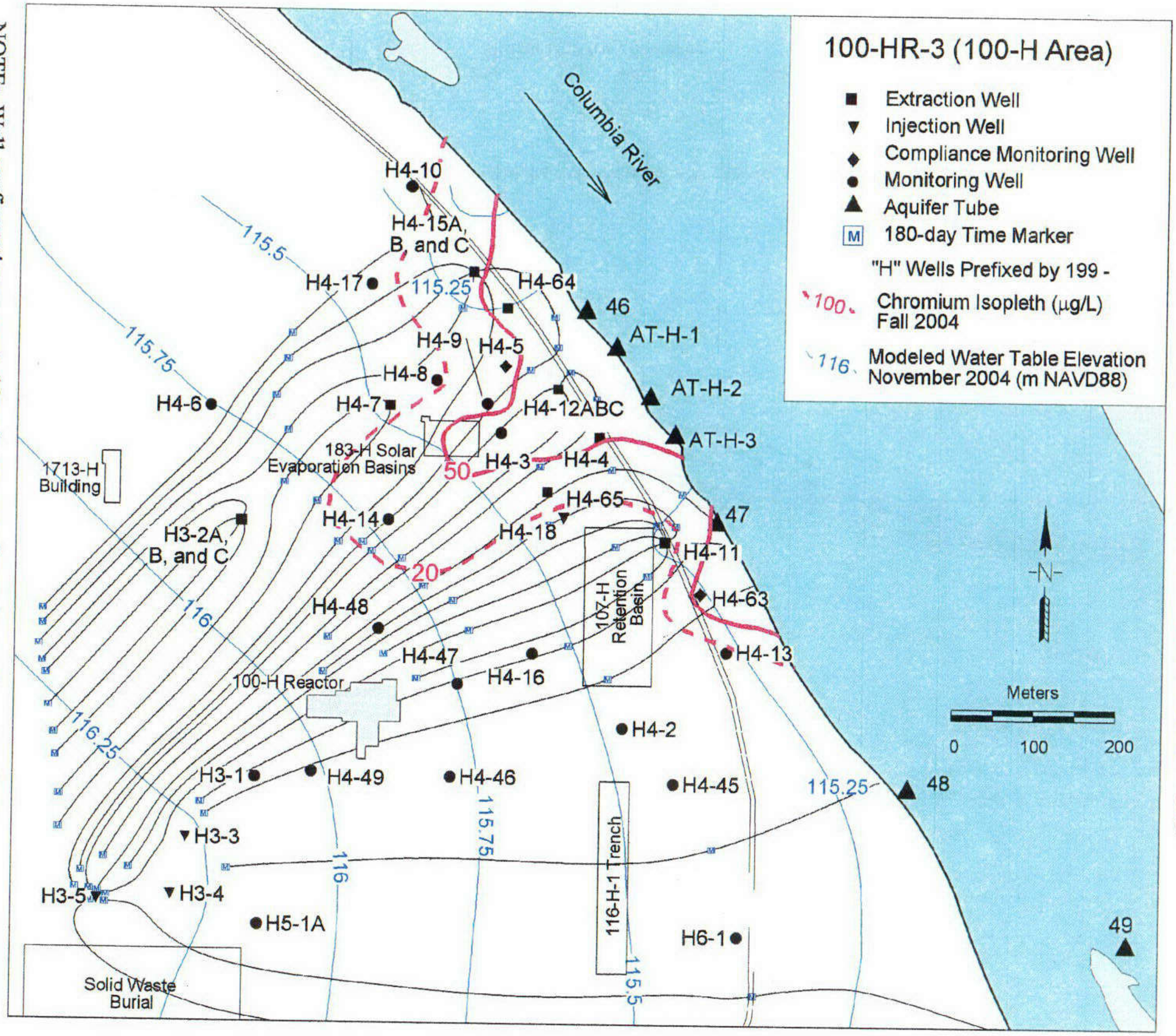


Figure 2-15. Estimated Steady-State Hydraulic Capture Zone Developed by 100-HR-3 Operable Unit, 100-H Area Extraction Wells.



NOTE: Well configuration presented is prior to reconfiguration in December 2004.

Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2004		Measured Water-Level Elevation, Nov. 2004 (m NAVD88[a])	Modeled Water-Level Elevation, Nov. 2004 (m NAVD88[a])
	Extraction Rate L/min	Injection Rate L/min		
100-H Area				
199-H3-2A	90.8	--	115.75	115.73
199-H4-7	40.1	--	115.09	115.27
199-H4-11	51.5	--	113.42	115.19
199-H4-12A	31	--	114.35	115.23
199-H4-15A	58.3	--	114.35	115.18
199-H4-65	0	--	115.27	115.38
199-H3-3	--	136.3	116.13	116.32
199-H3-4	--	220.7	116.27	116.41
199-H3-5	--	207.4	116.72	116.49
199-H3-2B	--	--	115.75	115.94
199-H3-2C	--	--	115.74	115.94
199-H4-4	--	--	115.11	115.25
199-H4-5	--	--	115.15	115.31
199-H4-8	--	--	115.28	115.42
199-H4-10	--	--	115.20	115.39
199-H4-12B	--	--	115.11	115.24
199-H4-12C	--	--	115.10	115.24
199-H4-15B	--	--	115.20	115.26
199-H4-63	--	--	115.00	115.18
199-H4-64	--	--	115.15	115.27
199-H4-48	--	--	115.75	116.18
199-H5-1A	--	--	116.14	116.32
100-H River	--	--	115.17	115.17
100-D Area				
199-D8-53	68.5	--	115.32	117.17
199-D8-54A	92.4	--	115.43	117.15
199-D8-68	109	--	116.88	117.08
199-D8-72	81.4	--	117.88	117.19
199-D5-20	36	--	--	115.08
199-D5-32	109.8	--	--	117.32
199-D5-37	15.1	--	--	117.39
199-D5-42	--	160.9	120.23	118.18
199-D8-69	--	--	117.08	117.20
199-D8-70	--	--	117.09	117.23
199-D8-71	--	--	117.05	117.22
100-D River	--	--	117.52	117.52

[a] NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

-- = No data available

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3.0 100-KR-4 PUMP-AND-TREAT SYSTEM

The 100-KR-4 OU includes the groundwater underlying the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 pump-and-treat facility is located along the Columbia River, several miles southwest of the 100-HR-3 OU (Figure 3-1). The 100-KR-4 treatment system and injection/extraction well field are located northeast of the KE Reactor and adjacent to the 116-K-2 mile-long disposal trench. A map of wells and aquifer tube locations in the 100-K Area is presented in Figure 3-2. Appendix A provides a history of operations and supporting documents used in the development of the 100-KR-4 pump-and-treat system. Appendix B presents the associated conceptual model.

The 100-KR-4 interim action is similar to the 100-HR-3 interim action in that the primary COC is hexavalent chromium. Interim action co-contaminants in the 100-KR-4 OU include tritium and strontium-90. Carbon-14 and nitrate are co-contaminants of interest.

This section provides the annual performance report for the 100-KR-4 OU. Primary emphasis is on pump-and-treat operations for the reporting period of January 1 through December 31, 2004. Section 3.1 summarizes groundwater conditions for all of the 100-KR-4 OU, as well as source area remedial actions within the groundwater OU. Section 3.2 summarizes the treatment system's performance, system operations, extraction well operations, and operational sampling. An evaluation of the aquifer response, including hydraulic monitoring, numerical modeling, and contaminant monitoring in the area impacted by pump-and-treat operations, is discussed in Section 3.3. Section 3.4 presents conclusions on the progress toward achieving each RAO and the performance criteria. Section 3.5 provides recommendations to change/enhance the 100-KR-4 OU pump-and-treat system. Cost information for the 100-KR-4 pump-and-treat system is presented separately in Section 5.0.

3.1 SUMMARY OF SOURCE AND GROUNDWATER OPERABLE UNIT ACTIVITIES

The long-term remedy for groundwater contamination in the 100-K Area requires both source and groundwater remedial actions.

3.1.1 Source Area Activities

BHI began excavation activities in both the 100-KR-1 and 100-KR-2 source OUs during 2004. The gas condensate cribs, which are the source of carbon-14 and tritium in groundwater near the KW and KE Reactors, were excavated and backfilled, and work then began to remove the upper 4.6 m of the mile-long trench. Consideration is also being given to installing a drain field in the bottom of the trench prior to backfilling. The drain field could be used to flush water or reductants through the vadose zone to either remove or treat (reduce) hexavalent chromium in the deeper vadose zone beneath the trench.

3.1.2 Groundwater Operable Unit Activities

The groundwater activities associated with the 100-KR-1 and 100-KR-2 source OUs are discussed in the following subsections.

3.1.2.1 100-KR-1 Operable Unit

Groundwater actions associated with 100-KR-1 consisted primarily of groundwater monitoring in the vicinity of the reactor areas, as reported in *Hanford Site Groundwater Monitoring for Fiscal Year 2004* (PNNL 2005). The primary emerging groundwater issue in this area is the localized hexavalent chromium plume near the KW Reactor building. The highest concentration during 2004 (560 μg/L) occurred in well 199-K-107A. Consideration is being given to applying a small-scale pump-and-treat system at this location or injecting a reductant (i.e., calcium polysulfide) to create a localized treatment cell. The calcium polysulfide approach will be field tested in CY05 at the downstream end of the 100-KR-4 OU as an alternative to expanding the pump-and-treat network in that area. If the treatability test is favorable, it may also be used at the KW Reactor's "hot spot" site.

3.1.2.2 100-KR-2 Operable Unit

Groundwater remedial actions in the vicinity of the 100-KR-2 source OU include the ongoing pump-and-treat operation in the vicinity of the 116-K-2 mile-long trench and the planned treatability test (as noted in Section 3.1.2.1). The 100-KR-4 pump-and-treat system began operation in 1997 as a containment and mass removal strategy to reduce the release of hexavalent chromium to the Columbia River in the vicinity of the mile-long trench. The primary source of the residual hexavalent chromium in the aquifer is attributed to the discharge of large volumes of reactor coolant containing approximately 700 μg/L of hexavalent chromium during operations from 1955 to 1971. A large groundwater mound developed around the mile-long trench, raising the water table to 6 m above the present-day water table elevation at a distance of over 1 km inland. There is evidence to suggest that coolant water may have also been transported inland to a distance of over 1 km from the trench. The long-term challenge for a final remedy is to address the widely distributed plume that may also be approaching the 100-N Area.

Other key groundwater issues being tracked in the 100-KR-1 OU include (1) fluctuating tritium concentrations near both reactor areas; (2) the occurrence of low, but measurable, technetium-99 concentrations near the KW Reactor that are of unknown origin; and (3) a possible tritium source near the burial ground (PNNL 2005).

Highlights associated with operation and improvements in the 100-KR-4 pump-and-treat system for CY04 are outlined below:

- Hexavalent chromium concentrations continued to decline in all of the extraction wells located in the vicinity of the mile-long trench. This suggests that cleanup of the aquifer between the injection and extraction wells is moderately effective. A much slower concentration response is evident at extraction well 199-K-112A, located 300 m beyond the northeastern end of the trench. This may be a result of residual chromium in the groundwater that was transported inland during the operating period and that is now migrating into the area between the end of the trench and the 100-N Area.
- Well 199-K-114A, located near the end of the mile-long trench, was converted to an extraction well in the fall of 2004 to enhance the hydraulic capture in this area. Concentrations at this well averaged 107 μg/L in October 2004. Well 199-K-126, located near an area of persistent high chromium concentration, reached a maximum of 97 μg/L in February 2004. Extraction rates from this well range to 227 L/min. Variations in pumping rates and chromium concentration can be attributed to changes in river stage.

This well will be used as an extraction well for the planned calcium polysulfide treatability test.

- In September 2004, well 199-K-131 was drilled at the northeastern edge of the chromium plume and constructed as a monitoring/extraction well. Based on samples taken in October 2004, elevated concentrations of hexavalent chromium (63 µg/L) were encountered, indicating again that the plume is approaching the 100-N Area.
- Aquifer tube data also demonstrate encroachment of the chromium plume between 100-K and the 100-N Area. For example, the highest tube concentration (67 µg/L) was for DK-04-03, located close to new well 199-K-131. This extension of the chromium plume may represent arrival of contaminated groundwater from reactor coolant that was pushed inland during the operation of the K Reactors and is now arriving at the shoreline at the downstream end of the OU. If this hypothesis is correct, a new long-term strategy will be needed to address hexavalent chromium in this area.
- Significant treatment plant improvements were made in 2004 that resulted in a combined estimated annual savings for the 100-KR-4 and 100-HR-3 systems of $500,000 per year. The change involved modifying the IX system so it now includes a sacrificial IX column of resin to remove uranium prior to removal of the chromium. Natural uranium that previously built up on the IX resin led to numerous instances where the uranium content exceeded offsite shipping standards. Consequently, the resin could not be regenerated and was disposed as a mixed waste at the ERDF.
- A new method for chromium treatment at 100-KR-4 has been proposed, accepted, and is currently under development. Calcium polysulfide has been identified as a sulfide-based reduction and metal fixation additive that may help remove hexavalent chromium in groundwater. Calcium polysulfide has been used successfully at a number of sites outside of Hanford to precipitate hexavalent chromium from groundwater. A treatability test plan has been approved (DOE-RL 2005c), and will be implemented in early CY05. Following bench-scale testing to quantify chemical addition requirements, a field treatability test will be conducted at well 199-K-126. Four injection wells will be drilled at equidistant spacing along a 30.5-m radius around the 199-K-126 extraction well. A calcium polysulfide solution will be injected in these wells, captured by pumping at the extraction well, and then held in tanks to settle the precipitated chromium. This system is scheduled to start in the spring of 2005 and is expected to run for 3 to 6 months. It may be extended to other wells or portions of the pump-and-treat system if it is successful in removing hexavalent chromium.

3.2 100-KR-4 TREATMENT SYSTEM PERFORMANCE

This section describes the 100-KR-4 pump-and-treat system's operations and sampling activities for CY04. Specific details include changes to system configuration, system availability, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and contaminant trends. A detailed discussion of this information is presented in the associated appendices.

One significant capital improvement modification was made on the original 100-KR-4 pump-and-treat system in March 2004. A resin-filled tank was added in front of the three resin-filled chromium treatment tanks. This vessel is filled with the same resin as the remainder of the system but is used to preferentially capture uranium in the groundwater. This saves the lead tanks' resins from becoming contaminated with uranium requiring disposal as a mixed waste, rather than being suitable for regeneration. Cost savings for this change are conservatively estimated at $500,000 per year for this and a similar system modification at 100-HR-3. Figure 3-3 presents the current system schematic of the pump-and-treat system for CY04.

A summary of operational parameters and total system performance for CY04 is presented in the table below:

Total processed groundwater:	
Total amount of groundwater treated (since October 1997 startup) (billion L)	2.83
Total amount of groundwater treated during CY04 (million L)	500
Mass of hexavalent chromium removed:	
Total amount of hexavalent chromium removed (since October 1997 startup) (kg)	257.6
Total amount of hexavalent chromium removed in CY04 (kg)	29.6
Summary of operational parameters:	
Removal efficiency (% by mass)	93.6
Waste generation (m^3)	80.5
Regenerated resin installed (m^3)	39
New resin installed (m^3)	41.5
Number of resin changeouts	35
Summary of system availability:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	277.5
Planned operations (hours)	8,506.5
Unscheduled downtime (hours)	76
Total time on-line (hours)	8,431
Total availability (%)	95.9
Scheduled system availability (%)	99.1

Key operational and system highlights for CY04 are as follows:

- The 93.6% removal efficiency for CY04 is lower than that reported for CY03 (Figure 3-4).
- The average 100-KR-4 influent hexavalent chromium concentration of 63 μg/L was lower than the CY03 average of 75.1 μg/L.
- The average effluent hexavalent chromium concentration of 4 μg/L for CY04 was comparable to 3.6 μg/L in CY03. Trend plots of CY04 influent and effluent concentrations are presented in Figure 3-5.
- The maximum hexavalent chromium concentration in the effluent was 16 μg/L.

- Scheduled system availability for CY04 was 99.1%, which was lower than the 99.3% reported in CY03. The total availability was 95.9%. This is a decrease from the on-line availability of 97.7% reported for CY03. The lower system availability values can be attributed to increased scheduled downtime for maintenance. Figure 3-6 presents the monthly on-line percentages and method used to calculate scheduled and on-line availability for the reporting period.
- During CY04, 35 IX vessels were changed out, generating 80.5 m^3 of spent resin. This amount is significantly lower than the 96.6 m^3 removed in CY03 and can be attributed to the lower volume of water processed during the current reporting period. As with the 100-HR-3 pump-and-treat system, resin changeouts were performed to maximize operating time and to limit the volume of material requiring regeneration or disposal.

The following table presents the pumping flow rates and total run-time (total flow hours / total possible run-time) for extraction wells at the 100-KR-4 pump-and-treat system. Except where noted, the recommended flow rates are based upon updated numerical modeling results that were prepared to support the *Comprehensive Environmental Response, Compensation, and Recovery Act of 1980* (CERCLA) 5-year review design modification. The yearly average flow rates are calculated from actual totalized volumes divided by the total hours in a year:

Well	Recommended Flow Rate (L/min)	Yearly Average Flow Rate (L/min)	Total Flow Hours in CY04	Total Run Time (%)[c]
199-K-129[a]	94.6	95.8	8,037	91.5
199-K-113A	94.6	53.8	8,074	91.9
199-K-114A[e]	94.6	84.8	792	9.0
199-K-115A	94.6	162	6,158	70.1
199-K-116A	151.4	168.1	7,897.5	89.9
199-K-119A	113.6	113.6	7,714.5	87.8
199-K-120A	113.6	151	7,731.5	88
199-K-125A	113.6	151.8	7,897	89.9
199-K-127	151.4	131	6,449	73.4
199-K-126[d]	54.1[b]	67.4	7,691.5	87.6

[a] Extraction well 199-K-112A was replaced with well 199-K-129, which began operating as an extraction well on July 10, 2003.
[b] Recommended flow rate based upon drawdown analysis.
[c] Total flow hours in CY04 / total hours in CY04 x 100%.
[d] Operated as an extraction well until July 2004.
[e] Monitoring well 199-K-114A was converted to an extraction well and began operation in November 2004.

A comparison of the extraction rates shows that wells 199-K-115A, 199-K-116A, 199-K-120A, 199-K-125A, and 199-K-126 were pumped at greater flow rates than recommended. These wells were able to sustain higher yields during the reporting period and were, therefore, used to offset lower rates from wells 199-K-113A and 199-K-127.

The lower-than-recommended flow rates at wells 199-K-113A and 199-K-127 may be attributed to fluctuations in river levels throughout the year, which limited the available drawdown in these wells. Decreased well efficiency due to scaling (calcium carbonate) or biological fouling may also impact pumping rates. During the year, all wells were subject to downtime because of area power-grid outages, equipment failures or maintenance, and construction activities. This downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentrations and extraction rates are provided in Appendix C.

3.3 AQUIFER RESPONSE IN THE 100-K AREA

This section describes the general hydrogeologic conditions in the 100-K Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

3.3.1 Hydrogeologic Conditions at the 100-K Area

The hydrogeologic conditions at the 100-K Area are as follows:

- The most prevalent groundwater flow direction is northwest, as shown in Figure 3-7. During spring and some summer months, the river elevation is generally higher due to increased run-off and increased dam releases to provide more irrigation water and aid fish migration. During higher river stage, flow is inland from the river to the aquifer. This creates a near-shore, short-term groundwater flow reversal from northwest to southeast that is clearly shown in Figure 3-8, where the April to July 2004 river elevations are higher than near-river wells.
- The maximum river stage was 0.15 m lower in CY04 than in CY03; similarly, the minimum Columbia River stage was 0.18 m lower in CY04. Overall, the average Columbia River stage was 0.08 m lower in CY04 than it was in CY03.
- The average hydraulic gradient in 100-K was 0.0007 toward the northwest, with a maximum gradient of 0.0021.
- The net groundwater flow velocity for 2004 over the 100-K Area was 0.053 m/day based on a hydraulic conductivity of 15.2 m/day, a porosity of 0.2, with the gradient of 0.0007 derived from a three-point solution of hourly data from wells 199-K-37, 199-K-18, and 199-K-117A.
- The average 2004 extraction well pumping rates ranged from 53.4 L/min in well 199-K-113A to 168.1 L/min in well 199-K-115. This compares to a range of 54.5 to 166.6 L/min in 2003, and a range of 53 to 153.3 L/min in 2002.

Appendix D presents a detailed discussion of the aquifer response in 100-KR-4. Appendix J presents hydrographs for 100-K Area wells.

3.3.2 Numerical Modeling

The following is a summary of the numerical modeling results supporting the 100-KR-4 pump-and-treat operations:

- The original targeted plume from the 116-K-2 Trench, north to the Columbia River, is within the capture zone of the existing extraction well network, as shown in Figures 3-9.

- The conversion of compliance well 199-K-126 to an extraction well in January 2003 has extended the capture zone further downstream to include an area where monitoring results have confirmed that chromium is above the 22 μg/L RAO. A detailed discussion of the numerical model is presented in Appendix F. Table 3-1 presents a comparison of the measured and modeled water table elevations, as well as the average flow rates used in the numerical model.
- An evaluation of aquifer dynamics based on estimated travel time between injection and extraction wells along capture zone flow lines (Figure 3-9) resulted in the following observations:
  - Travel times (Figure 3-9) for the central portion of the original extraction well network suggest that two to three aquifer pore volumes have been extracted since operations began in 1997. Much longer estimated travel times (i.e., 10 to 15 years) from the injection wells to the northeastern extraction wells, and the far southwestern end, indicate that a longer time will be required to achieve the same degree of cleanup as in the central area of the plume.
  - The decline in chromium concentrations predicted for two central extraction wells is consistent with observed concentrations (see the lower right-hand corner of Figure 3-7). A simple washout model (Appendix F) was used to predict the rate of decline in chromium concentrations, assuming no new input of chromium to the aquifer. A linear projection based on this model suggests that the RAO may be met prior to 2006 for the portion of the aquifer in the capture zone of wells 199-K-119A and 199-K-125A.
  - The relatively close agreement between observed and predicted chromium concentrations implies that the aquifer cleanup rate is controlled primarily by aquifer turnover or travel time between injection and extraction wells. This also implies that there may not be significant input from vadose zone sources; otherwise, the observed chromium concentrations would depart significantly from the predicted concentrations (Figure 3-7). If so, then vadose zone treatment to remove residual chromium may not be needed. Alternatively, decreasing the travel time between injection and extraction wells would be more effective in reducing the chromium concentrations in that portion of the aquifer (southwestern and northeastern ends) where chromium is declining very slowly.
  - The preliminary aquifer dynamics evaluation presented in Appendix F and summarized above emphasizes the importance of evaluating alternative approaches to treating the distal ends of the 100-KR-4 groundwater OU.

3.3.3 Contaminant Monitoring

This section summarizes and interprets the CERCLA analytical results obtained from groundwater monitoring wells supporting the 100-K Area pump-and-treat remedial action. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1997b) and *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY04. The results presented below are the average annual concentrations for CY04, unless otherwise specified. Section 3.3.3.1 includes a discussion on chromium monitoring results, and Section 3.3.3.2 includes a discussion about monitoring results for remedial action co-contaminants strontium-90 and tritium. Nitrate and carbon-14 are also constituents of interest.

Complete contaminant monitoring results for CY04 and the historical results for CY97 through CY03 are presented in Appendix G. A summary and highlights for CY04 are discussed below.

- Chromium concentrations decreased in all nine extraction wells. In four wells, chromium decreased more than 20%; however, concentrations remained above the RAO of 22 µg/L in all extraction wells. The maximum average chromium concentration in an extraction well was 93.5 µg/L in well 119-K-126. Chromium concentrations decreased in three of four compliance wells, remaining above the RAO of 22 µg/L in wells 199-K-18, 199-K-20, and 199-K-114A. The maximum chromium concentration in a compliance well was 136.3 µg/L in 199-K-18; the lowest was 7.1 µg/L in well 199-K-117A.
- The farthest downstream monitoring well, 199-K-131, had an average chromium concentration of 63 µg/L. This well became operational as a monitoring well in October 2004.
- The largest average strontium-90 concentration was measured in well 199-K-21 at 39.2 pCi/L in October 2004.
- Tritium was above the 20,000 pCi/L MCL in three pump-and-treat area wells. The highest concentration was 43,000 pCi/L in extraction well 199-K-120A.

3.3.3.1 Chromium Monitoring Results

Chromium concentrations are monitored in extraction wells, compliance wells, monitoring wells and aquifer tubes in the pump-and-treat operational area. Additional CERCLA monitoring wells outside of the area affected by pump-and-treat operations are also sampled for chromium.

The 100-K Area chromium plume and associated historical trends for 2004 are displayed in Figure 3-7. The table below compares the CY03 versus CY04 averaged chromium analytical results for extraction wells, compliance wells, and selected monitoring wells where the reported values exceeded the 22 µg/L RAO or the percent change was greater than 20%. The results shown are for filtered hexavalent chromium, unless indicated otherwise:

Well Name	Well Use	CY03 Average (µg/L)	CY04 Average (µg/L)	Percent Change[a]
199-K-18	Compliance	123.8	136.3	+10%
199-K-19	Monitoring	78.5	66.5	-15%
199-K-20	Compliance	68.8	54.8	-20%
199-K-21	Monitoring	38	25.7	-32%
199-K-22	Monitoring	140	128.5	-8%
199-K-32A	Monitoring	12.4[c]	20.5[c]	+65%
199-K-37	Monitoring	73	84.0	+15%
199-K-113A	Extraction	68.2	51.0	-25%
199-K-114A	Compliance	66.5	65.4	-2%
199-K-115A	Extraction	107.7	83.0	-23%
199-K-116A	Extraction	122.5	80.7	-34%
199-K-117A	Compliance	9.7	7.1	-27%

Well Name	Well Use	CY03 Average (μg/L)	CY04 Average (μg/L)	Percent Change[a]
199-K-119A	Extraction	49.8	37.0	-26%
199-K-120A	Extraction	77	71.5	-7%
199-K-125A	Extraction	45	37.0	-18%
199-K-126[b]	Extraction	105	93.5	-11%
199-K-127	Extraction	66	54.5	-17%
199-K-129	Extraction	67.5	52.5	-22%
199-K-130	Monitoring	60.2	92.9	+54%
199-K-131	Monitoring	--	63.0	NA

[a] Percent change = (CY04 - CY03) / CY03 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
[b] Well 199-K-126 converted to extraction well (from compliance well) in November 2004.
[c] Filtered total chromium.
-- = well not sampled or analytical results not available for report preparation
NA = not applicable

Chromium concentrations decreased from 2003 to 2004 in all nine of the extraction wells and decreased 20% or more in five of the extraction wells. Chromium concentrations increased in one compliance well (by 10% in well 199-K-18) and decreased in three compliance wells, to a maximum of 27% in well 199-K-117A. Chromium trends in the monitoring wells were varied. About one-half of the wells showed a decrease and one-half of the wells showed an increase from 2003 to 2004. The largest decrease was 32% in well 199-K-21, and the maximum increase was 65% in well 199-K-32A.

Aquifer tube sites at 100-KR-4 were sampled during late February and early March 2004. These sites are located along the river and are adjacent to the reactors and the 116-K-2 Trench area. The largest chromium concentration measured in CY04 was 67.2 μg/L at tube DK-04-03, which is located approximately 750 m downriver of the northeast end of the 116-K-2 Trench. Of the total aquifer tubes sampled in CY04, nine sites exceeded the 22 μg/L RAO.

3.3.3.2 Co-Contaminant Monitoring Results

Strontium-90 and tritium are listed in the 100-KR-4 ROD (EPA et al. 1996) as co-contaminants. Nitrate and carbon-14 are contaminants of interest that also are monitored as part of the CERCLA sampling program. The co-contaminant monitoring results are summarized as follows:

- **Strontium-90:** One compliance well (199-K-114A), three monitoring wells (199-K-19, 199-K-21, and 199-K-22), and two extraction wells (199-K-113A and 199-K-115A) were characterized by strontium-90 above the 8 pCi/L MCL. The maximum 2004 strontium-90 concentration was 39.2 pCi/L in monitoring well 199-K-21. The overall trend is somewhat downward, with six wells showing a concentration decrease, three wells showing an increase, six wells showing nondetects, and the remaining three wells are without CY03 data for comparison. The maximum increase was 27% in monitoring well 199-K-127; the maximum decrease was 33% in well 199-K-120A. The 2003 versus 2004 results for selected wells and percent change are summarized in the table below:

Well	Type	CY03 Sr-90 (pCi/L)[c]	CY04 Sr-90 (pCi/L)[c]	Percent Change[d]
199-K-18	Compliance	0.2(U) (±0.21)	0.2(U) (±0.3)	NA
199-K-19	Monitoring	a	10.3 (±0.8)	NA
199-K-20	Compliance	6.4 (±1.1)	5.8 (±0.6)	-9%
199-K-21	Monitoring	a	39.2 (±1.4)	NA
199-K-22	Monitoring	7.1 (±1.2)	8.9 (±0.8)	+25%
119-K-113A	Extraction	11.5 (±2.8)	9.8 (±2.0)	-3%
199-K-114A	Compliance	20.2 (±3.1)	19.2 (±1.0)	-5%
199-K-115A	Extraction	8.8 (±2)	9.2 (±1.8)	+7%
199-K-116A	Extraction	5.6 (±1.1)	3.4 (±0.8)	-31%
199-K-117A	Compliance	2.2[b] (±0.49)	2.0 (±0.4)	-9%
199-K-119A	Extraction	a	-0.04(U) (±0.4)	NA
199-K-120A	Extraction	1.4 (±0.5)	0.9 (±0.5)	-33%
199-K-125A	Extraction	a	-0.2 (±0.4)	NA
199-K-126A[e]	Extraction	a	0.2(U) (±0.5)	NA
199-K-127	Extraction	3.0 (±1.6)	3.2 (±0.8)	+27%
199-K-129	Extraction	a	-0.04(U) (±0.4)	NA
199-K-130	Monitoring	-0.2 (U) (±0.2)	0.2(U) (±0.3)	NA
199-K-131	Monitoring	a	0.2(U) (±0.3)	NA

[a] Not sampled during 2003.
[b] Averaged result.
[c] Results rounded to one decimal place. Numbers in parentheses represent counting error.
[d] (2004 - 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
[e] Well 199-K-126 was converted to an extraction well (from compliance well) in November 2004.
NA = percent change not applicable because of nondetect or not sampled previous year
U = nondetected in sample above contracted detection limit

Strontium-90 was only detected at four aquifer tube sites that were sampled. The maximum level was 1.38 pCi/L in aquifer tube 21-M, downgradient of the 116-K-2 Trench.

- **Tritium:** Four of the wells sampled for tritium had concentrations above the 20,000 pCi/L MCL in CY03, while only three wells were above the MCL in CY04. The CY03 tritium results are compared to the CY04 results in the table below for the four wells that were above 20,000 pCi/L in 2003. The overall tritium trend showed a strong decline in CY04.

Well	Type	CY03 Tritium (pCi/L)	CY04 Tritium (pCi/L)	Percent Change[a]
199-K-18	Compliance	44,275 (±2,600)	34,850 (±540)	-21%
199-K-32A	Monitoring	51,375 (±2,075)	29,300 (±645)	-43%
199-K-111A	Monitoring	46,460 (±1,940)	16,175 (±478)	-65%
199-K-120A	Extraction	64,950 (±9,750)	43,000 (±8,600)	-34%

[a] (2004 – 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

It is important to note that all of the wells listed above are located at the western end of the 116-K-2 Trench. The source of this tritium may be the 116-K-2 Trench and/or a previously unknown plume beneath the 100-K burial ground that has been displaced to the west by the mounding created by the injection network (PNNL 2002).

Of the wells sampled for tritium in CY04, well 199-K-106A had a concentration of 389,600 pCi/L, which is a decrease of 36% from the CY03 value of 612,000 pCi/L. The CY03 and CY04 results for the wells in the 100-K Reactor areas that were above the 20,000 pCi/L MCL are summarized in the table below:

Well	Type	CY03 Tritium (pCi/L)	CY04 Tritium (pCi/L)	Percent Change[a]
199-K-27	Monitoring	69,448 (±961)	50,675 (±860)	-27%
199-K-29	Monitoring	17,530 (±815)	32,925 (±688)	+88%
199-K-30	Monitoring	264,550 (±10,725)	370,833 (±2,050)	+40%
199-K-32A	Monitoring	51,375 (±2,075)	29,300 (±645)	-43%
199-K-106A	Monitoring	612,000 (±21,640)	389,600 (±2,340)	-36%
199-K-109A	Monitoring	44,000 (±1,850)	32,775 (±650)	-26%

[a] (2004 - 2003) / 2003. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

The maximum tritium concentration for aquifer tubes sites sampled was 11,900 pCi/L at AT-K-3, downgradient from the 116-K-2 Trench.

- Carbon-14: All of the wells sampled for Carbon-14 are located outside the pump-and-treat area. The maximum concentration of 2,510 pCi/L was detected in well 199-K-29. The carbon-14 concentration trend varied in these wells from 2003 to 2004. The maximum carbon-14 concentrations in 2003 and 2004 and the annual changes are summarized in the table below for the two wells above the MCL of 2,000 pCi/L:

Well	Type	CY03 C-14 (pCi/L)	CY04 C-14 (pCi/L)	Percent Change[a]
199-K-29	Monitoring	2,620 (±98)	2,510 (±25)	-4%
199-K-34	Monitoring	3,050 (±110)	2,340 (±24)	-23%

[a] (2004 - 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

Carbon-14 was only detected at two of the aquifer tube sites sampled. Site AT-K-1 had the highest at a level at 22.5 pCi/L, while AT-K-2 had a concentration of 20.1 pCi/L. Both sites are located downgradient from the K East Reactor.

- **Nitrate:** The maximum nitrate concentration for wells sampled within the pump-and-treat area was 91.2 mg/L in compliance well 199-K-18. Nearby well 199-K-111A was also above the MCL at 52.5 mg/L nitrate; however, the other wells in the pump-and-treat area all had nitrate concentrations below the MCL of 45 mg/L. The CY03 and CY04 concentrations in the 10 wells and the percent change are summarized in the table below (note that all concentrations are reported as nitrate):

Well	Type	CY03 NO_3 (mg/L) (as Nitrate)	CY04 NO_3 (mg/L) (as Nitrate)	Percent Change[b]
199-K-18	Compliance	96.2	91.2	-5%
199-K-19	Monitoring	23.0	34.5	+50%
199-K-20	Compliance	11.1	11.5	+4%
199-K-21	Monitoring	[a]	29.0	N/A
199-K-22	Monitoring	15.9	16.8	+6%
199-K-32A	Monitoring	24.2	28.1	+16%
199-K-32B	Monitoring	9.5	8.9	-6%
199-K-37	Monitoring	11.1	10.2	-8%
199-K-111A	Monitoring	52.0	52.5	+1%
199-K-117A	Compliance	8.4	7.1	-15%

[a] Not sampled in 2003.
[b] (2004 - 2003) / 2003 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
NA = data not available for year to year comparison

Samples from monitoring wells in the reactor areas were also analyzed for nitrate in 2004. The concentrations ranged from 7.5 mg/L in well 199-K-110A to 113.5 mg/L in well 199-K-106A. Four of the wells had concentrations above the 45 mg/L MCL, including well 199-K-108A. This well had low concentrations (0.3 mg/L) of nitrate in CY03 but much higher concentrations (75.9 mg/L) in CY04. Septic system drain fields and decontamination solutions containing nitric acid are the possible sources of this contaminant.

- **Technetium-99 and sulfate in aquifer tubes:** Technetium-99 was detected only at aquifer tube site 14-D at a concentration of 119 pCi/L. This site is located upriver of the reactor area. The MCL for technetium-99 is 900 pCi/L.
- **Sulfate:** The maximum sulfate concentration was 69.7 mg/L in aquifer tube 26-D. This site is located the farthest downriver from the 116-K-2 Trench. The secondary drinking water MCL for sulfate is 250 mg/L).

Appendix G presents sample results for CY04 as well as a historical summary of contaminant and co-contaminant monitoring results for wells and aquifer tubes. Associated contaminant trend charts are presented in Appendix K.

3.4 QUALITY CONTROL RESULTS FOR 100-K MONITORING DATA

The QC results for the 100-K sampling included field testing or laboratory testing for hexavalent chromium and total chromium. Additionally, laboratory tests were run for strontium-90 and tritium.

A summary of QC data for 100-KR-4 in CY04 are summarized in the table below. A complete listing of QC results is found in Appendix I.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Field replicates (hexavalent chromium)	13	12	92%
Field/laboratory split (hexavalent chromium)	23	21	91%
Laboratory replicates (total chromium)	22	12	55%
Laboratory replicates (nitrate)	4	4	100%
Offsite/onsite laboratory splits (nitrate)	2	2	100%
Laboratory replicates (strontium-90)	4	3	75%
Offsite/onsite laboratory splits (strontium-90)	5	5	100%
Laboratory replicates (tritium)	4	4	100%
Offsite/onsite laboratory splits (tritium)	3	0	0%

The EPA's functional guideline for field-tested replicates is an RPD of <20% (EPA 1988). All field replicates, with the exception of one (with a RPD of 43%), satisfied this requirement. There are no functional guidelines for split results or laboratory replicates. All QC results are satisfactory, except the laboratory replicates for total chromium and the laboratory splits for tritium. The tritium split QC results can be considered marginally acceptable because, even though all RPDs were above 20% (the largest RPD was 26.5%), the results were just above the acceptable limit of 20%. The QC results indicate that total chromium results are not consistent between onsite (i.e., Hanford) and offsite laboratories. Since offsite laboratories were seldom used to analyze data, the results of the analyses should be accepted.

3.5 CONCLUSIONS

- ***RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.***

  The RAO cleanup goal for compliance wells is 22 μg/L based on the 11 μg/L ambient water quality criterion in place at the time of the signing of the ROD (EPA et al. 1996).

  Results:

  - Approximately 500 million L of groundwater were treated during 2004, and 29.6 kg of hexavalent chromium were removed.
  - Chromium concentrations decreased in all extraction wells but remained above the RAO of 22 μg/L in all of the extraction wells. The maximum chromium concentration in an extraction well was 93.5 μg/L in well 119-K-126. This well is the most recent extraction well, having been converted from a compliance well in

January 2003. Chromium concentrations decreased in three of four compliance wells and remained above the RAO of 22 μg/L in wells199-K-18, 199-K-20, and 199-K-114A. The maximum chromium concentration in a compliance well was 136.3 μg/L in well 199-K-18; the lowest was 7.1 μg/L in well 199-K-117A.

- The two farthest downstream monitoring wells, 199-K-130 and 199-K-131, had average 2004 chromium concentrations of 92.9 μg/L and 63 μg/L, respectively, indicating that the plume extends toward the northeast.
- The maximum strontium-90 concentration in the pump-and-treat area of influence was at compliance well 199-K-21. The concentration was 39.2 pCi/L for strontium-90 in 2004.
- Three pump-and-treat area wells had tritium concentrations above the 20,000 pCi/L MCL. The wells showed concentration decreases of between 21% and 43% from the CY03 levels. The maximum concentration was 43,000 pCi/L in extraction well 199-K-120A, which is a decrease of 34% compared to 2003.
- The area enclosed by the 100 μg/L chromium isopleth has remained the same size since November 2003 but has decreased in size when compared to the 1995 baseline 100-K Area chromium plume.
- Monitoring well 199-K-131 was installed in March 2004 to supplement characterization of the downstream portion of the chromium plume. Analytical results from this well indicate that the chromium plume extends toward the northeast but at decreasing concentrations when compared to well 199-K-130.

- ***RAO #2: Protect human health by preventing exposure to contaminants in groundwater.***

  Result: The interim remedial action ROD establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

  - Access control and visitor escorting requirements
  - Signs providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents.

  The effectiveness of institutional controls was presented in the *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a). The findings of the report indicate that institutional controls were maintained to prevent public access, as required.

- ***RAO #3: Provide information that will lead to a final remedy.***

  Results: Operational data and improvements, as well as special studies and technical reviews, provide information that should contribute to a final remedy. Progress during 2004 included the following:

- Improved cost efficiency in operation of the existing 100-KR-4 treatment plant achieved during 2004 makes pump-and-treat operations more attractive as one potential component of a final remedy. Also, information from the new MR3 pilot plant tested in the 100-D Area during 2004 suggests that further reductions in IX column treatment costs may be possible.
- A DOE-sponsored expert panel/workshop on evaluation of pump-and-treat operations at the Hanford Site was held during 2004. Findings for 100-KR-4 included the need for improved modeling to better understand the distribution of hexavalent chromium in the aquifer. Improved transport modeling may help decide which portions of the contaminated aquifer are amenable to pump-and-treat and which are not. Other considerations were discussed in a final report.
- Plans were made during 2004 to field test a new technology, in situ/ex situ calcium polysulfide treatment, at 100-KR-4. If successful, this technology will be considered for use as part of a treatment train that may be appropriate for a final remedy.
- Related to the above, consideration was given to soil column treatment (deep vadose zone source control) using soil flushing or fixation in-place with reducing agents as one potential piece of a final remedy treatment train.

3.6 RECOMMENDATIONS

- Implement the expert panel's recommendations to conduct numerical modeling of hexavalent chromium transport in groundwater during reactor operations and during the post-shutdown period to the present time. This information will help in developing a long-term strategy and remedy to address the widely distributed, but relatively low, hexavalent chromium concentrations in the vicinity of the 116-K-2 Trench and the surrounding area.
- Rehabilitate existing boreholes and or use other low-cost drilling methods to better delineate the distribution of the chromium plume to the east and northeast of the mile-long trench. Numerical modeling can be used to select optimum location(s) for new test borings.
- Evaluate application of the calcium polysulfide in situ/ex situ method for treatment of the hexavalent chromium hot spot near the KW Reactor building.
- Evaluate technologies that can be used to identify a possible chromium source in the 100-KW and 100-KE reactor area.

Figure 3-1. Location of the 100-KR-4 Operable Unit.

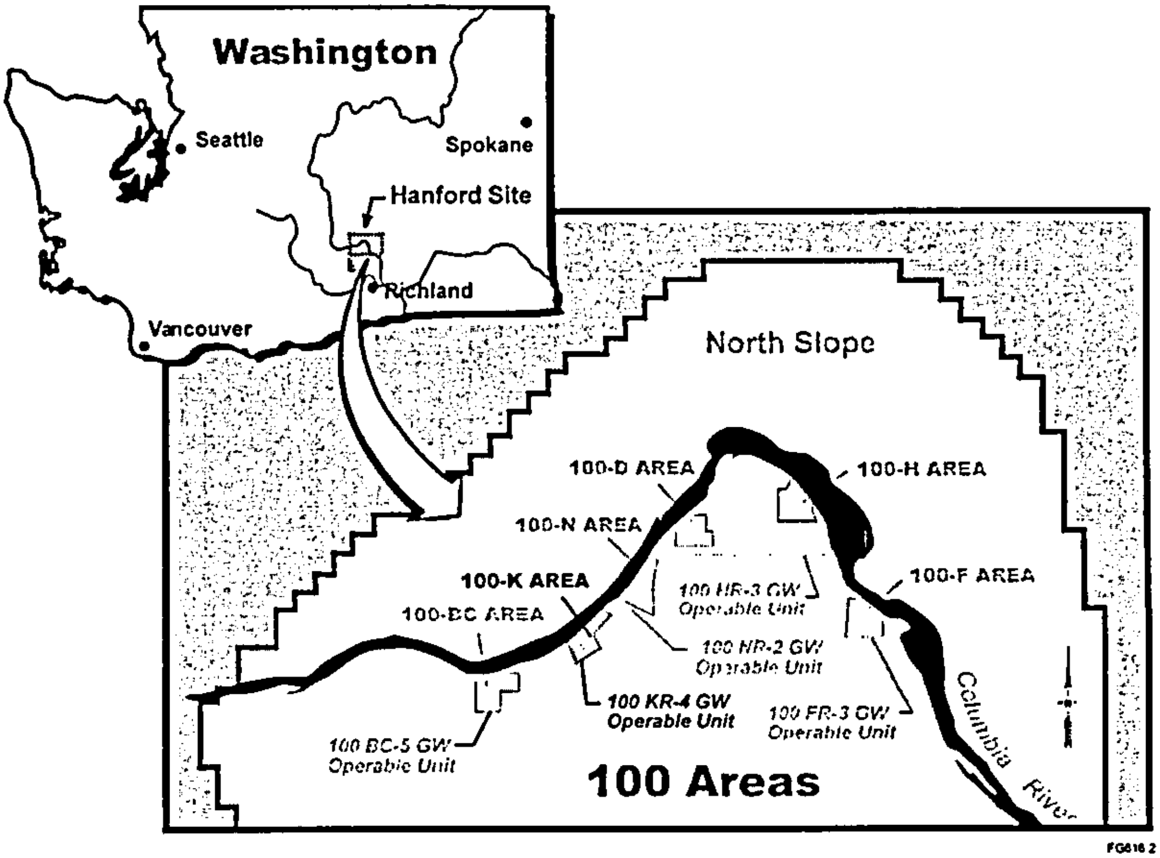
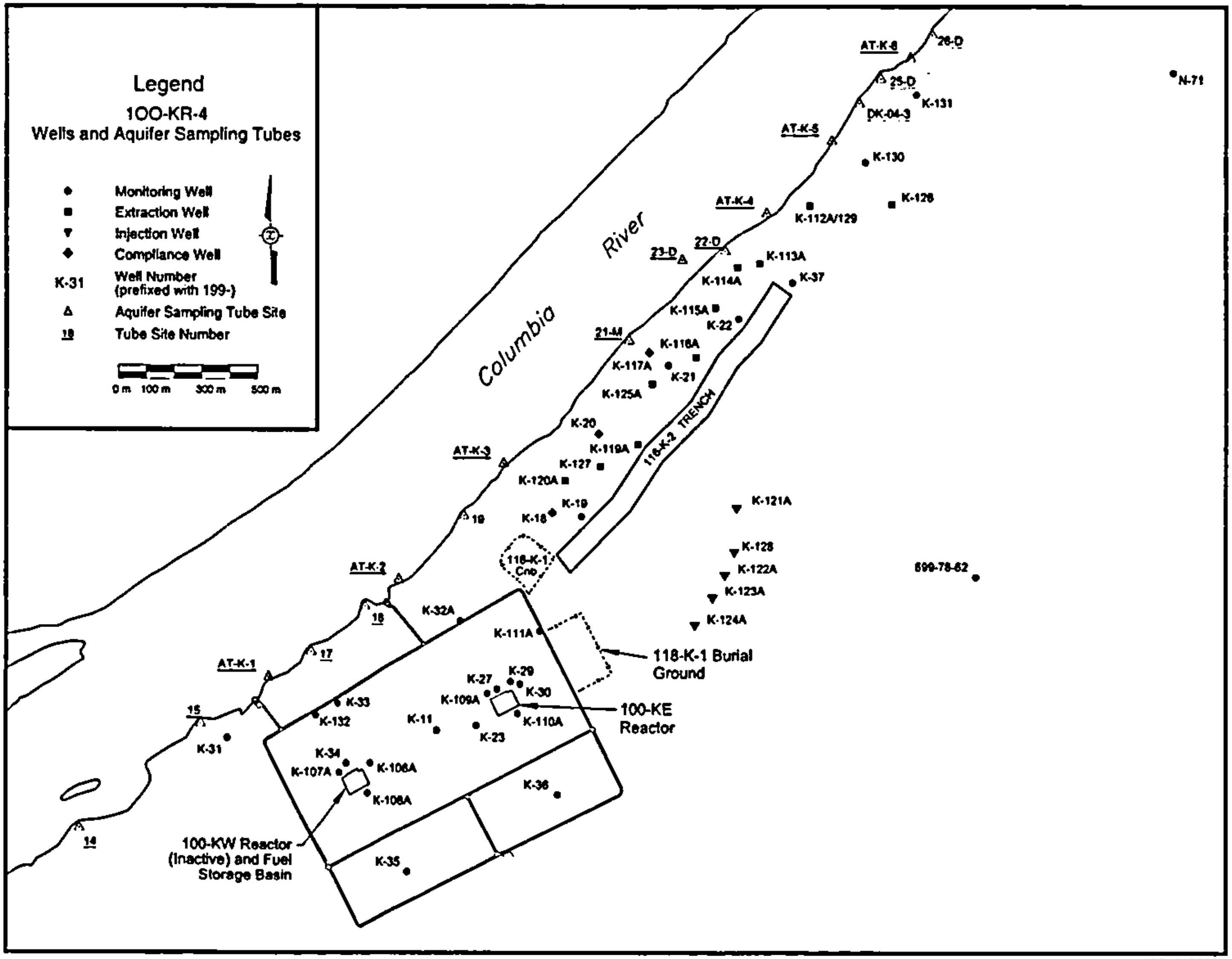
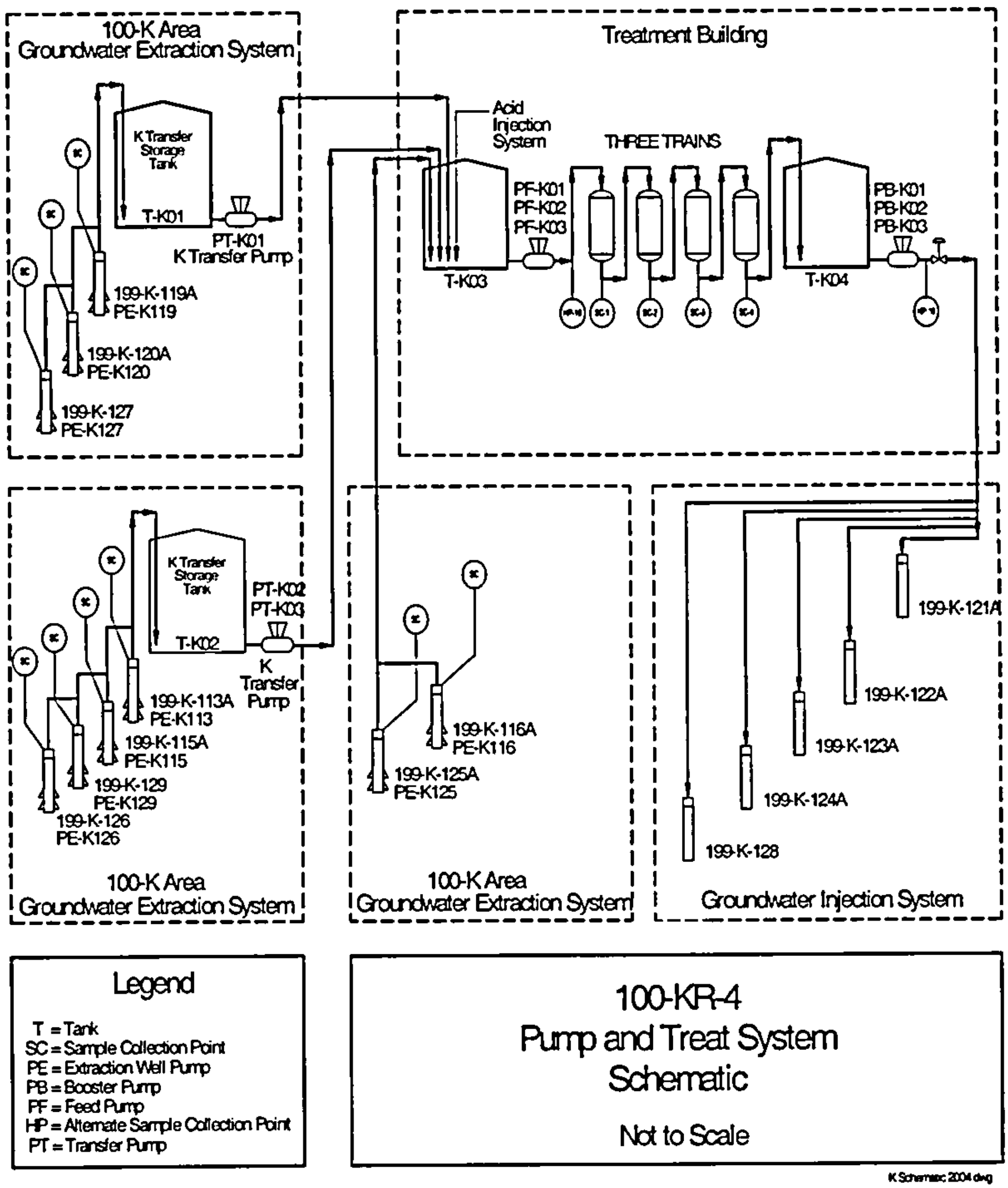


Figure 3-2. 100-KR-4 Operable Unit Wells and Aquifer Sampling Tubes.



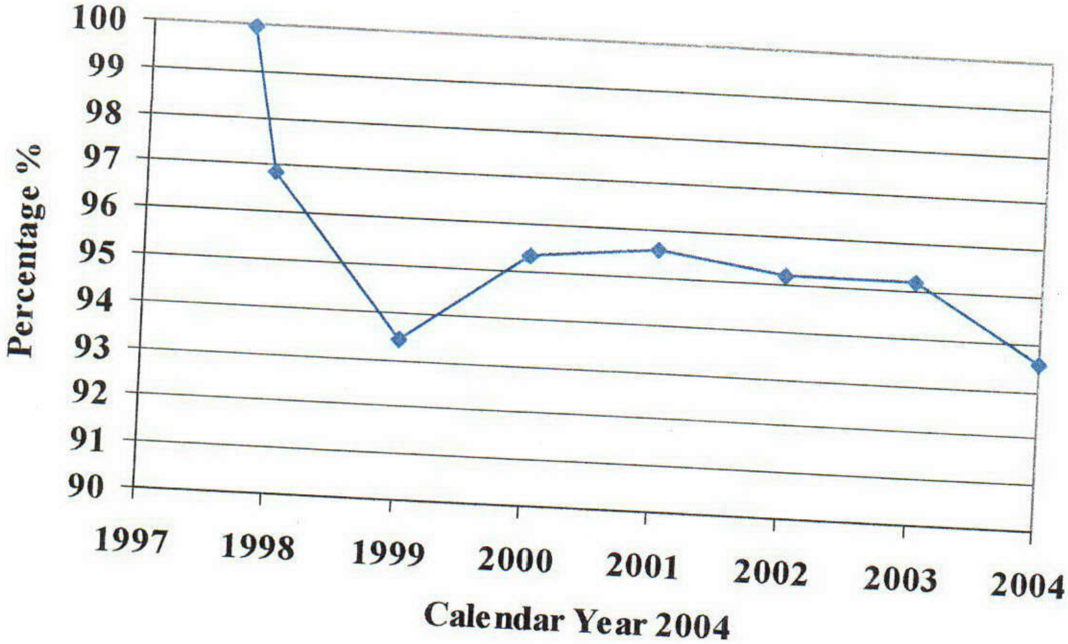
100-K (2005)

Figure 3-3. 100-KR-4 Operable Unit Pump-and-Treat System Schematic.



NOTE: Monitoring well 199-K-114A was converted to an extraction well in late November 2004.

Figure 3-4. 100-KR-4 Pump-and-Treat Trends of Average Removal Efficiencies.



Average removal efficiency (% by mass) = [(influent – effluent) / influent].

Figure 3-5. 100-KR-4 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations, Calendar Year 2004.

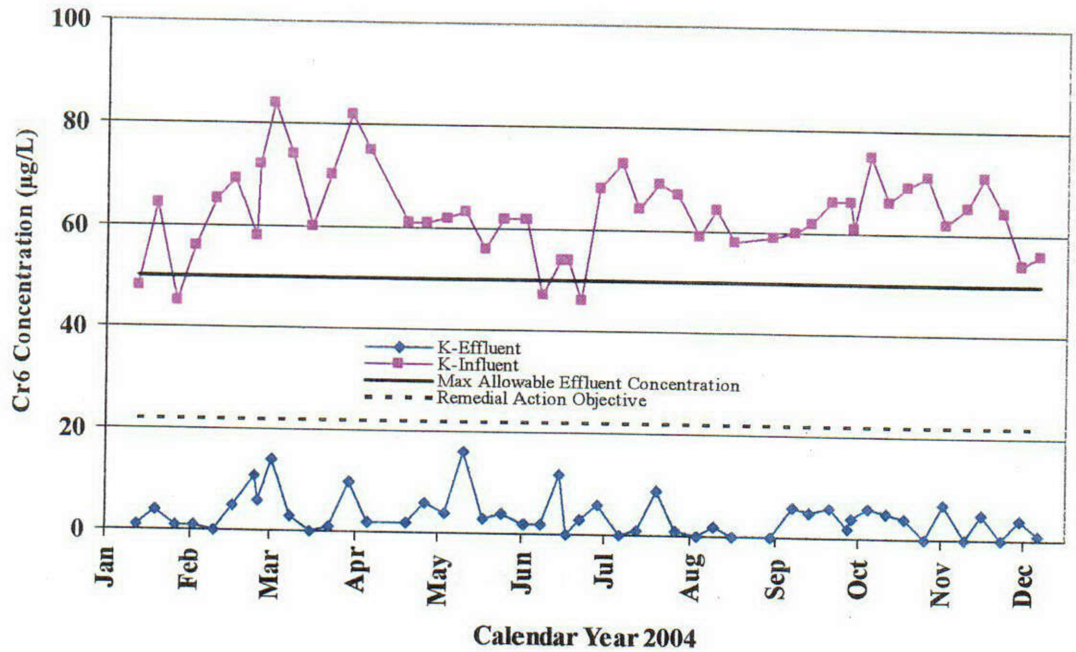
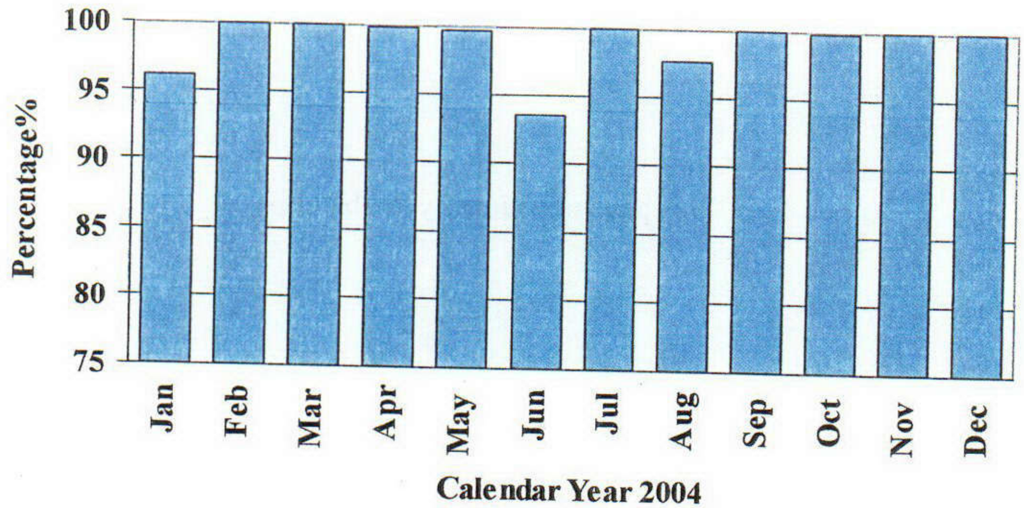


Figure 3-6. 100-KR-4 System Availability and On-Line Percentages for Calendar Year 2004.



Summary of system availability:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	277.5
Planned operations (hours)	8,506.5
Unscheduled downtime (hours)	76
Total time on-line (hours)	8,431
Total availability (%)	95.9
Scheduled system availability (%)	99.1

Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].

Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible run-time)].

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Figure 3-7. 100-KR-4 Chromium Plume, Fall 2004.

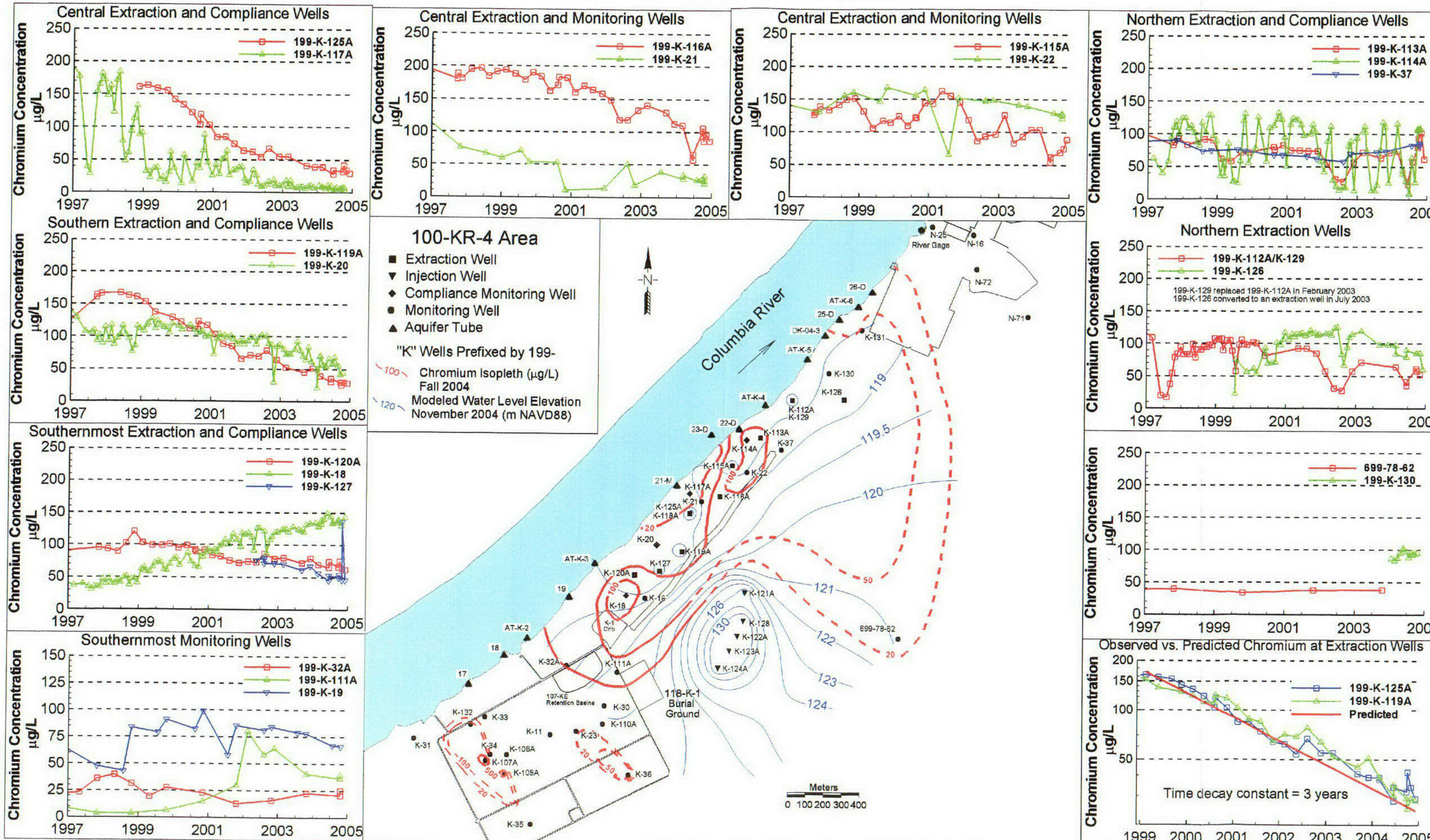
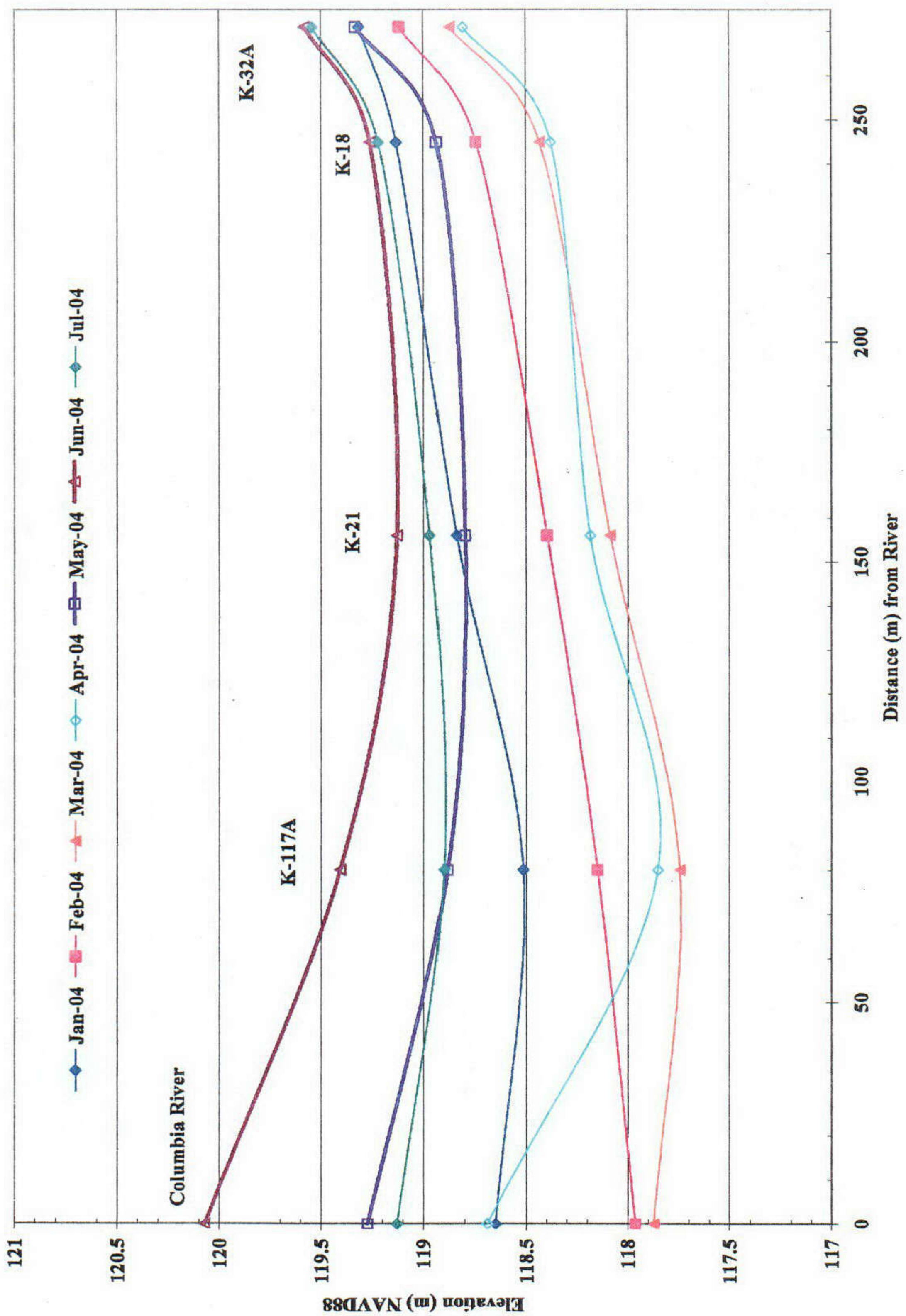


Figure 3-8. Water Elevation Versus Distance from the Columbia River in 100-K Area Wells.



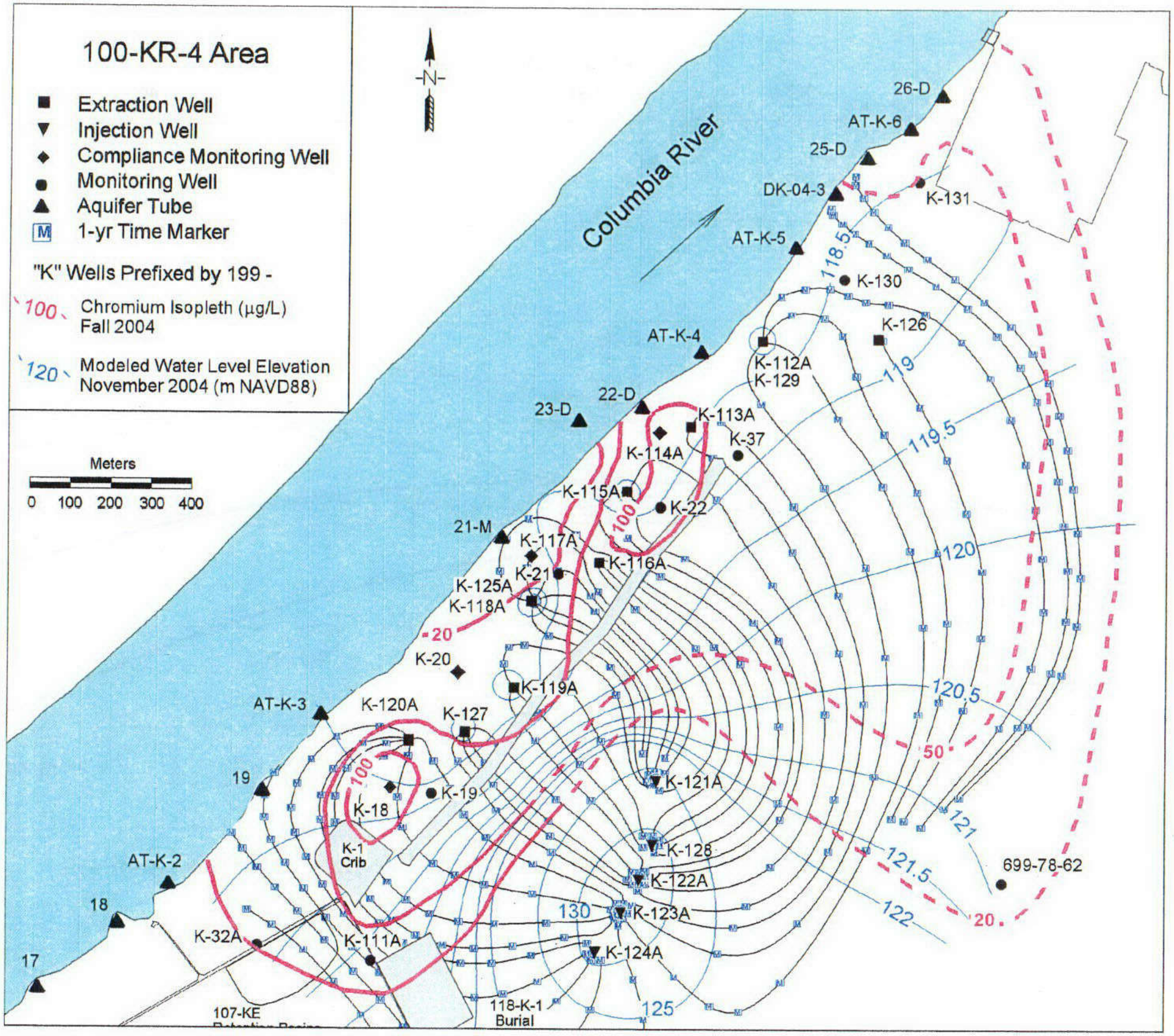


Figure 3.9. Estimated Steady-State Hydraulic Capture Zone Developed by 100-KR-4 Operable Unit Extraction Wells.

Table 3-1. 100-KR-4 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2004		Measured Water-Level Elevation, Nov. 2004 (m NAVD88[a])	Modeled Water-Level Elevation, Nov. 2004 (m NAVD88[a])
	Extraction Rate L/min	Injection Rate L/min		
199-K-129	98.4	--	117.89	116.39
199-K-113A	56.8	--	116.62	116.31
199-K-115A	164.7	--	115.91	115.42
199-K-116A	170.3	--	118.42	118.64
199-K-119A	113.6	--	116.64	116.12
199-K-125A	151.4	--	118.28[b]	114.84[c]
199-K-126	60.6	--	119.20	118.12
199-K-127	132.5	--	117.00	116.51
199-K-120A	151.4	--	117.93	117.94
199-K-121A	--	200.6	121.44	132.36
199-K-122A	--	232.8	125.21	147.44
199-K-123A	--	249.8	129.87	150.71
199-K-124A	--	81.4	127.09	138.35
199-K-128	--	259.3	126.49	143.83
199-K-18	--	--	118.59	118.59
199-K-19	--	--	118.67	118.78
199-K-20	--	--	118.38	118.19
199-K-21	--	--	118.39	118.55
199-K-22	--	--	118.32	118.59
199-K-37	--	--	118.70	118.86
199-K-114A	--	--	118.97	118.38
199-K-117A	--	--	118.40	118.43
199-K-118A	--	--	117.30	117.17

[a] NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

-- = No data available

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4.0 100-NR-2 PUMP-AND-TREAT SYSTEM

The 100-NR-2 Groundwater OU is located along the Columbia River between the 100-KR-4 OU and the 100-HR-3 OU (Figure 4-1). The 100-NR-2 OU consists of the groundwater underlying and in the vicinity of the source OUs that are associated with the 100-N Area. The 100-NR-2 pump-and-treat system is currently operating to reduce the flux of contaminated groundwater to the Columbia River and to remove strontium-90 from the aquifer. Figure 4-2 shows the location of the extraction and injection wells and the associated compliance and monitoring wells in relation to the primary facilities. Appendix A provides a history of operations and supporting documents used in the development of the 100-NR-2 pump-and-treat system.

This section provides the annual performance report for the 100-NR-2 pump-and-treat system required by the *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999). The purpose of this section is to report treatment system and aquifer performance data collected during 2004 and to describe progress toward meeting the goals described in the ROD.

The following subsections summarize and evaluate the performance of the pump-and-treat system, the response of the aquifer in relation to these goals, and the OU contaminants. Section 4.1 provides a brief overview summary of activities pertaining to the 100-NR-2 pump-and-treat system and the source area remedial actions that have occurred within the OU for CY04. Section 4.2 focuses on treatment system performance. Section 4.3 describes aquifer response, including the baseline conditions, hydraulic effects, numerical modeling, contaminant changes during the pump-and-treat operations, and contaminant distributions and trends throughout the OU. Section 4.4 presents the updated conceptual model. Section 4.5 discusses the QC of the analytical samples. Conclusions and recommendations are presented in Section 4.6. Cost information is presented separately in Section 5.0.

4.1 SUMMARY

Progress on source removal and groundwater remediation activities for CY04 is summarized below.

4.1.1 100-NR-1 Operable Unit

The interim action ROD (EPA et al. 1996) requires that the most significant soil contamination in the 100-NR-1 OU be addressed first. Cleanup of the remaining surface and subsurface sites will occur in the future in order of priority, as established by the regulatory agencies. The status and activities at the most contaminated soil sites include the following:

- Cleanup of the major strontium-90 source areas, the 116-N-1 and 116-N-3 Cribs, continued during the year. Excavation to a depth of approximately 4.6 m bgs was completed at 116-N-3 and was nearly complete at 116-N-1.
- The excavated 116-N-3 Crib was backfilled and contoured to match the adjacent undisturbed topography. The mounded or sloped surface of the backfill should reduce infiltration of moisture into the underlying vadose zone.

4.1.2 100-NR-2 Operable Unit

The activities required for the 100-NR-2 OU by the interim ROD to address strontium-90 and other contaminants in groundwater near the source areas consist of (1) operating a pump-and-treat system, (2) maintaining a groundwater monitoring network for tracking changes in contaminant concentrations, (3) investigating alternative treatment technologies, (4) assessing ecological risk of contaminated groundwater, and (5) removing any free product (e.g., diesel) in monitoring wells. The progress for these activities during CY04 is outlined below:

- The pump-and-treat system removed approximately 0.2 Ci during the year, for a total of 1.6 Ci, or only about 2% of the aquifer inventory since the beginning of operations in 1995. Maintenance and repair frequency increased, and a decline in removal efficiency during the year required more frequent changeout of the spent IX media, resulting in an increase in operating costs. The marginal effectiveness of the pump-and-treat remedy to reduce near-shore strontium-90 concentrations in groundwater and increasing operating costs suggest that termination of the pump-and-treat operations should be given serious consideration.
- Network monitoring well data indicate very little change in strontium-90 concentrations compared to prior years, especially near the shoreline. Also, three new wells near the shoreline and aquifer tubes were installed by Pacific Northwest National Laboratory (PNNL) to support an evaluation of the effectiveness of pump-and-treat to reduce the flux of strontium-90 to the river. Elevated manganese and iron persist in well 199-N-18, which is attributed to biodegradation of residual diesel in the aquifer that creates anoxic (reducing) conditions.
- A letter report on the evaluation of alternative strontium-90 treatment technologies was completed in October 2004 (bhi-erc.com/projects/risk/risk_library.htm) and was submitted to the Washington State Department of Ecology (Ecology). A public workshop was held on December 8, 2004, to discuss the findings and recommendations of the report. Laboratory and field studies were also conducted by PNNL to support the evaluation of a proposed treatment train that includes apatite sequestration (primary), phytoremediation (secondary), and natural attenuation. A treatability test plan based on the December 8 workshop and the supporting laboratory studies will be prepared in 2005. Installation of test facilities for one or more of the candidate treatment approaches is planned for 2006.
- A 100-NR-2 ecological risk data quality objectives (DQO) summary report and sampling and analysis plan (SAP), including reconnaissance sampling (spring 2004) to support the DQO process, were completed in CY04 (DOE-RL 2005a). The SAP will guide CY05 field work for an ecological risk report that is due in October 2005. Findings will also support decisions concerning the location and extent of alternative treatment needed to reduce shoreline concentrations of strontium-90 and possibly other COCs (e.g., diesel and the related occurrence of elevated manganese and iron).
- Diesel fuel was removed from the only remaining monitoring well (199-N-18) with observable free product. Diesel in grab samples of water collected during 2004 also appears to have declined in comparison to 2003 and prior years. In addition, the SAP for the ecological risk assessment includes petroleum hydrocarbon sampling (planned for 2005) along the shoreline near this spill site.

4.2 100-NR-2 TREATMENT SYSTEM PERFORMANCE

This section summarizes the CY04 treatment system operations and sampling activities. This information includes system availability, mass of contaminants removed during operations, contaminant removal efficiencies, and quantity and quality of extracted and disposed groundwater. Additional operational details are found in the associated appendices, as referenced in this report.

4.2.1 System Operation

The treatment facility includes an IX system that uses a natural zeolite (clinoptilolite) to remove strontium-90 from the extracted groundwater. In 2004, no major operational modifications were made that changed the performance of the pump-and-treat system. Figure 4-3 presents the current system process flow. A summary of operational parameters for CY04 and for total performance is as follows:

Total processed groundwater:	
Total since September 1995 startup (million L)	1,026.8
Total for CY04 (million L)	107.2
Mass of strontium-90 removed:	
Total since September 1995 startup (Ci)	1.63
Total for CY04 (Ci)	0.15
Average total flow rate of extraction wells for CY04 (L/min)	204
Average extraction well production range (L/min)	22 to 110
Average percent removal[a]	83
Summary of 2004 operational parameters:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	337
Planned operation (hours)	8,447
Unscheduled downtime (hours)	830.5
Total time on-line	7,616.5
Total availability (%)	86.7
Scheduled system availability (%)	90.2

[a] Average percent removal, based upon the percent average removed each clino-period for CY04.

Key operational and system highlights for CY04 are as follows:

- The scheduled system availability of 90.2% for CY04 was lower than the 97.6% reported in CY03. The total availability was 86.7%, which was slightly lower than the 88.8% reported for CY03. The lower performance percentages were partially the result of a higher rate of unscheduled downtime in July 2004 and the increased changeout of the spent IX media. The monthly on-line percentages and method used to calculate scheduled and on-line availability are presented in Figure 4-4.
- The average percentage removal of strontium-90 during CY04 was 83% compared to 88.8% in CY03 and 90% in CY02. The lower removal efficiency during CY04 is attributed to the use of a different source of clinoptilolite than in previous years because

the old source was no longer available. Due to the decline in removal efficiency, which reached a low of 75% in August 2004, the changeout cycle was reduced from every 4 weeks to every 3 weeks. Another contributing factor to the loss in removal efficiency may be a change ionic composition of the extracted groundwater. For example, there are some indications that the sulfate plume from the 1324-N crib is being drawn into the southwestern side of the pump-and-treat capture zone.

- As shown in Figure 4-5, the CY04 average influent activity for strontium-90 was 1,970 pCi/L. The average effluent activity for strontium-90 was 499 pCi/L. These values are slightly higher than the CY03 in value of 1,878 pCi/L and effluent value of 327 pCi/L.
- Historical presentation of operational parameters, total system performance, and activities for influent and effluent are provided in Appendix C.

4.3 AQUIFER RESPONSE AT THE 100-N AREA

This section describes the general hydrogeologic conditions in the 100-N Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

4.3.1 Hydrogeologic Conditions at the 100-N Area

The hydrogeologic conditions at the 100-N Area are as follows:

- The most prevalent groundwater flow direction is northwest, as shown in Figure 4-6. During the spring months, the river elevation is generally higher due to increased run-off and to provide more irrigation water and aid fish migration. This creates a near-shore, short-term groundwater flow reversal from northwest to southeast is clearly shown in Figure 4-7, where the April to June 2004 river elevations are higher than near-river wells. This phenomenon was also seen in the January 2004 water-level data.
- The maximum river stage was 0.15 m lower in FY04 than in FY03; similarly, the minimum Columbia River stage was 0.18 m lower in FY04. Overall, the average Columbia River stage was 0.08 m lower in FY04 than it was in FY03.
- The average hydraulic gradient in the 100-N Area was 0.0005 toward the northwest, with a maximum gradient of 0.0014.
- The net groundwater flow velocity for 2004 over the 100-K Area was 0.37 m/day based on a hydraulic conductivity of 15.2 m/day, porosity of 0.2, with the gradient derived from a three-point solution of hourly data from wells 199-N-50, 199-N-3, and 199-N-14.
- The average 2004 extraction well pumping rates ranged from 42 L/min in well 199-N-75 to 126.8 L/min in well 199-N-106A. This compares to a range of 40.1 to 143.8 L/min, respectively, in 2003 and 39 to 138.2 L/min, respectively, in 2002.

Appendix D presents a detailed discussion of aquifer response at 100-NR-2. Appendix L presents hydrographs for 100-N Area wells.

4.3.2 Numerical Modeling

A summary of the numerical modeling results supporting the 100-NR-2 pump-and-treat operations is as follows:

- The strontium-90 pump-and-treat plume is within the 2004 modeled capture zone of the 100-NR-2 extraction well network, as shown in Figure 4-8.
- The modeled November 2004 flow lines in Figure 4-8 compare very closely with the predicted capture flow lines in --*Springs Expedited Response Action Performance Evaluation Report* (DOE-RL 1996a). This comparison suggests that the pump-and-treat system performance is consistent with the results of the predicted model. A detailed discussion of the numerical model is presented in Appendix F. Table 4-1 presents a comparison of the measured and modeled water table elevations, as well as the average flow rates used in the numerical model.
- Figure 4-8 shows time markers spaced 1 year apart on the flow lines, based on the high November steady-state velocities. The northern-most flow line is located in a very high conductivity region of the 100-N Area, based on the 1-year time markers being approximately 900 m apart on this flow line, which is equivalent to a pore velocity of about 2.5 m/day. The time markers in the center of the extraction well system shows much slower flow velocities of about 0.3 m/day (e.g., in front of extraction well 199-N-75). The November velocities are expected to be the highest velocities during the year. The effective porosity was set to a low value of 0.1, which also increases the calculated pore velocities.

4.3.3 Contaminant Monitoring

This section summarizes the 100-N Area groundwater monitoring results collected to support the interim remedial action and OU monitoring program during CY04. An engineering change notice, *Modifications to the Groundwater Sampling and Analysis Schedules for the 100-NR-2 Operable Groundwater Sampling Project and 100-N Area RCRA Monitoring Program* (ECN M-15-96-08 [FDH 1996]), defines the sampling protocols implemented for CY04. The results presented below are the average annual concentrations for CY04, unless otherwise specified.

The principal groundwater COCs in the 100-N Area are strontium-90, tritium, chromium, manganese, sulfate, and petroleum hydrocarbons. CERCLA sampling is conducted in March and September.

4.3.3.1 Strontium-90 Monitoring Results

The configuration of the strontium-90 plume has remained relatively unchanged since the startup of pump-and-treat operations. Figure 4-6 displays the CY04 strontium-90 plume and associated historical trends.

The highest average strontium-90 concentration was found in well 199-N-67, which was measured at 7,203 pCi/L (±2.3 pCi/L). This well is located downgradient of the 1301-N Liquid Waste Disposal Facility (LWDF) and has declined from 26,000 pCi/L in March 1998. The greatest increase in average strontium-90 concentration from 2003 to 2004 was detected in extraction well 199-N-103A, which increased from 233 pCi/L (±48 pCi/L) to 321 pCi/L (±67 pCi/L).

Aquifer tubes were sampled for strontium-90 five times during 2004. Concentrations ranged from a low of 118 pCi/L in aquifer tube NS-4 to a high of 3,830 pCi/L in tube NS-3. Results for aquifer tubes are summarized in Appendix G. Average strontium-90 data for wells that had a greater than 20% change from 2003 to 2004 are summarized below:

Well	Type	CY03 Average Sr-90 (pCi/L)	CY04 Average Sr-90 (pCi/L)	Percent Change[a]
199-N-75	Extraction	424 (±72)	254 (±24)	-40%
199-N-103A	Extraction	233 (±48)	321 (±67)	+39%
199-N-105A	Extraction	724 (±130)	390 (±8.8)	-46%
199-N-2	Monitoring	117 (±21)	55.95 (±11.8)	-52%
199-N-46	Monitoring	4,070 (±700)	2,370 (±27)	-42%

[a] (CY04 – CY03) / CY03 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

4.3.3.2 Contaminants of Concern Monitoring Results

Other COCs in the 100-N Area include tritium, chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons (EPA et al. 1999). The results of the COC monitoring for CY04 are summarized as follows:

- **Tritium:** Concentrations for tritium overall appear to be stable or declining. The highest average tritium concentration, 25,300 pCi/L (±553 pCi/L), was in well 199-N-14, located northwest of the 1301-N LWDF. Average tritium concentrations were above the 20,000 pCi/L MCL in three wells sampled during CY04 compared to five wells sampled in CY03. Tritium data are summarized in the table below for wells in which average concentrations changed more than 20% from 2003 to 2004, or where average concentrations were above the 20,000 pCi/L MCL. The estimated amount of tritium remaining in the area of the recirculation cell between the extraction and injection wells is approximately 2 Ci as of 2004. The tritium in the area of the recirculation cell is hydraulically controlled and prevented from discharging to the river.

Well	Type	CY03 Average H-3 (pCi/L)	CY04 Average H-3 (pCi/L)	Percent Change[a]
199-N-14	Monitoring	30,700 (±1,400)	25,300 (±553)	-18%
199-N-32	Monitoring	25,100 (±1,200)	21,200 (±510)	-15%
199-N-46[b]	Monitoring	73 (±160)	282 (±99.1)	+286%
199-N-50	Monitoring	12,600 (±1,310)	9,700 (±350)	-23%
199-N-75	Extraction	20,400 (±1,000)	15,200 (±447)	-26%
199-N-76	Monitoring	22,400 (±1,100)	22,900 (±507)	-2%
199-N-80	Monitoring	21,700 (±1,100)	17,500 (±1,100)	-19%
199-N-96A	Monitoring	3,735 (±295)	2,310 (±183)	-38%
199-N-99A	Monitoring	3,550 (±290)	365 (±115)	-90%

[a] (CY04 – CY03) / CY03 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
[b] Well 199-N-46 is subject to variation in tritium concentrations due to dilution by river water.

- **Chromium:** Chromium contamination does not appear to be a widespread problem in the 100-N Area and was detected above 22 μg/L only in well 199-N-80, which was completed in the first producing horizon in the confined aquifer. The average CY04 concentration for this well was 170 μg/L and is similar to the 168 μg/L concentration measured in CY03. The source of the elevated chromium is uncertain but may be from deterioration of the stainless-steel well casing.

  The highest CY04 filtered total chromium concentration in a well screened in the unconfined aquifer in the 100-N Area was 15.7 μg/L in well 199-N-64. Aquifer tubes measured for chromium were predominately at detection limits.

- **Manganese:** Manganese is elevated above the 50 μg/L MCL in wells 199-N-16, 199-N-18, 199-N-26, and 199-N-119. The average CY04 concentrations for these wells were 735 μg/L, 2,480 μg/L, 88.9 μg/L, and 76.1 μg/L, respectively. The only aquifer tube above the 50 μg/L MCL was NS-2A at 62.4 μg/L. Well 199-N-18 is located adjacent to a diesel spill site, and the source of the elevated manganese may be due to diesel additives, corrosion of the steel casing, and/or reducing conditions caused by degradation of the residual diesel fuel still present in the aquifer. Likewise, well 199-N-16 is located downgradient from other historic diesel spill sites, and dissolved oxygen has been low in this well; thus, the cause of the elevated manganese at this site also may be related to petroleum hydrocarbon. The cause of elevated manganese in well 199-N-26 is unknown, while elevated values in well 199-N-119 and aquifer sampling tube NS-2A are most likely due to drilling effects associated with their recent installation.

- **Nitrate:** Average CY04 nitrate concentrations exceeded the 45 mg/L MCL in monitoring wells 199-N-2, 199-N-3, 199-N-21, 199-N-26, 199-N-32, 199-N-67, and 199-N-105A and in aquifer tube 50-M. Nitrate concentrations vary greatly in the 100-N Area wells. For example, the average nitrate concentration at well 199-N-67 was 55 mg/L in CY02 and increased to 212 mg/L in CY04. The source of the nitrate is unknown at this time.

  Nitrate data are summarized in the table below for wells in which the average concentration changed more than 20% from 2003 to 2004, or where average concentrations were above the 45 mg/L MCL:

Well	Type	CY03 Average NO_3 (mg/L)	CY04 Average NO_3 (mg/L)	Percent Change[a]
199-N-2	Monitoring	49.8	87.3	+75%
199-N-3	Monitoring	63.9	66.1	+3%
199-N-16	Monitoring	39	9.9	-75%
199-N-21	Monitoring	49.1	48.0	-2%
199-N-26	Monitoring	57.5	81.9	+42%
199-N-32	Monitoring	56.3	62.4	+11%
199-N-67	Monitoring	186	212	+14%
199-N-71	Monitoring	7.08	8.9	+26%
199-N-73	Monitoring	15.9	23.0[b]	+45%

199-N-74	Monitoring	7.08	10.2	+44%
199-N-76	Monitoring	32.5	44.3	+36%
199-N-77	Monitoring	13.7	24.3	+77%
199-N-99A	Monitoring	15.1	19.3	+28%
199-N-105A	Extraction	40.7	57.1	+40%

[a] (CY04 – CY03) / CY03 x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.
[b] Detected at less than the contract-required detection limit but greater than the instrument or method detection limit.

- **Sulfate:** None of the wells or aquifer tubes sampled for sulfate in CY04 had average concentrations above the 250 mg/L secondary drinking water standard. Sulfate data are summarized in the following table for wells in which concentrations changed more than 20% from 2003 to 2004:

Well	Type	CY03 Average SO_4 (mg/L)	CY04 Average SO_4 (mg/L)	Percent Change[a]
199-N-16	Monitoring	141	64	-55%
199-N-96A	Monitoring	117.5	84.6	-28%

[a] (CY04 – CY03) / CY03 x 100%. >+20% = increasing and <-20% = decreasing.

- **Petroleum hydrocarbons:** Well 199-N-18 monitors the area of 100-N where a 300,000-L petroleum leak occurred during the 1960s. The total petroleum hydrocarbons (TPH)-diesel range fluctuated from 440 mg/L in September 2002, to 630,000 mg/L in March 2003, and to 350 mg/L in September 2003. The CY04 average for this well was 183 mg/L. The March 2003 sampling also noted an inch of free product in this well. Similarly, the average annual TPH-gasoline range concentration in this well has declined from 15 mg/L in CY02, to 8.56 mg/L in CY03, and to 2.125 mg/L in CY04.

  A passive treatment method to remove diesel from well 199-N-18 was deployed in October 2003. This approach was chosen because the layer of floating petroleum was too thin for removal by active remediation methods. The passive method uses a polymer (Smart Sponge™) with a molecular structure that selectively absorbs petroleum from the surface of the water (i.e., a sponge) while the device floats at the air/hydrocarbon/water interface. A bundle of four, 0.3-m -long cylinders of the material are lowered into the well for a 2-week period, after which the cylinders are removed, weighed, and replaced with a new pre-weighed bundle.

  The average mass removal rate for CY04 was 0.4 kg/month. The free-product capacity of one absorbent cylinder is about 0.4 kg of fuel, or 1.6 kg for a bundle of four. Accordingly, a changeout frequency of bi-monthly or quarterly appears to be adequate to remove the free product that migrates into the well.

  Monitoring well 199-N-96A, located downgradient from well 199-N-18, has had average annual TPH-diesel range and TPH-gasoline range concentrations below the method detection limits in both CY03 and in CY04.

Smart Sponge™ is a trademark of AbTech Industries, Scottsdale, Arizona.

Appendix G presents the sample results for CY04, as well as a historical summary of contaminant and co-contaminant monitoring results for wells and the aquifer. Associated contaminant trend charts are presented in Appendix M.

4.4 100-NR-2 CONCEPTUAL MODEL UPDATE

The conceptual model for strontium-90 contamination at the 100-N Area is discussed in detail in the *N-Springs Expedited Response Action Performance Evaluation Report* (DOE-RL 1996a). Groundwater chemistry data, water-level data, and operational information gathered since 1995 continue to support the original conceptual model. This update will briefly describe the 1995 conceptual model and provide information about source removal since that time.

The main sources of strontium-90 contamination are the 1301-N LWDF (also known as the 116-N-1 Facility) and the 1325-N LWDF (also known as the 116-N-3 Facility). The 1301-N Facility operated from 1964 to September 1985. The 1325-N Facility operated from 1983 to 1991. These facilities received liquid wastes from N Reactor that contained strontium-90, cobalt-60, cesium-137, plutonium, and tritium. Tritium was transported through the soil column with the liquid wastes, reaching and then moving with the groundwater. Cesium-137, cobalt-60, and plutonium were concentrated in the upper portion of the soil column beneath the LWDFs. Strontium-90 was spread throughout the soil column and into the upper aquifer.

The upper aquifer in the 100-N Area is contained in the Ringold Unit E facies of the Ringold Formation. The base of the upper aquifer is the Ringold Upper Mud Unit. The Ringold Unit E sediments at the 100-N Area are composed of sandy gravel to sandy silt. Strontium-90 is adsorbed onto the aquifer solids and is in equilibrium with dissolved-phase strontium-90. Dissolved-phase strontium-90 that is removed by pump-and-treat operations will come back into equilibrium with the adsorbed phase when extraction ceases. It should also be noted that adsorbed strontium-90 on aquifer solids from past discharges occurs near the shoreline, based on core samples from well 199-N-95A (DOE-RL 1995).

Dissolved-phase strontium-90 likely extends into the riverbed to some extent based on the concentration isopleths shown in Figure 4-6. This source is beyond the influence of the pump-and-treat capture zone, as illustrated later. However, based on sediment core profiles from near the shoreline and near the 1301-N Trench, the expected concentrations of adsorbed strontium-90 in the riverbed should be an order of magnitude lower than in the more central portion of the capture zone in the vicinity of the 1301-N Trench. Additional details regarding the adsorption-desorption process can be found in DOE-RL (1996a). The long-term behavior of strontium-90 (and tritium) in pore fluid in the near-shore aquifer and its implications for a remedial action conceptual model are discussed in the following paragraph.

The concentration history of strontium-90 and tritium in groundwater at the shoreline are shown in Figure 4-9. The data are from monitoring wells 199-N-8 and 199-N-46, which are located adjacent to each other, near the center of the strontium-90 plume. This monitoring location was used to report estimated annual flux of strontium-90 and other contaminants to the river to comply with a National Pollutant Discharge Elimination System discharge permit (1301-N/ 1325-N Cribs). During the operating years, water pumped from well 199-N-8 was sampled continuously and composited monthly for analysis. After 1990, when water was no longer discharged to the soil column from N Reactor operations, only periodic grab samples were collected from adjacent well 199-N-46. Thus, the more recent strontium-90 results are more erratic, probably reflecting a fluctuating water table (river stage) at the time of sample collection.

Nevertheless, the general historical trends of strontium-90 and tritium results shown in Figure 4-9 illustrate two important points relevant to a groundwater remedial action conceptual model:

- Due to the well-known adsorption-desorption kinetics of strontium-90, elevated pore-fluid concentrations persist in the near-shore aquifer long after crib discharges cease and after startup of the pump-and-treat system.
- In sharp contrast to strontium-90, the exponential loss of tritium (which is an ideal tracer for the movement of groundwater) indicates that there is a decoupling between the near-shore stream bank storage zone and the more inland portion of the aquifer impacted by the pump-and-treat capture zone. For example, tritium concentrations persist in monitoring wells that lie between the extraction wells and the injection wells, suggesting a continuing recirculation cell.

These observations suggest that the pump-and-treat system has had little, if any, measurable impact on the near-shore groundwater concentrations of strontium-90, as predicted by previous numerical modeling. Thus, for remedial action purposes, the near-shore aquifer or stream bank storage zone must be considered as a separate, semi-isolated portion of the aquifer that requires a different approach to control strontium-90 concentrations in the near-shore aquifer and discharge to the river.

The January 1995 strontium-90 inventory for the 1301-N and 1325-N LWDF soil column and underlying saturated zone was 1,866 Ci. In this total, 88 Ci were estimated adsorbed to soil particles in the saturated zone and 0.8 Ci were dissolved in groundwater (DOE-RL 1996a). The remaining inventory was assumed to be absorbed to soil particles in the vadose zone beneath the LWDFs.

4.4.1 Inventories and Flux

The total strontium-90 inventory is estimated to have decayed to 1,467 Ci at the end of CY04, not including strontium-90 removed during source area excavation. This calculation was based on a strontium-90 half-life of 28.8 years. During the 10-year period from January 1995 to December 2004, the strontium-90 inventory was reduced 363 Ci by natural decay. The 100-NR-2 pump-and-treat system, operating from September 1995 through December 2004, removed 1.6 Ci of dissolved strontium-90 from the saturated zone. This represents about 2% of the total 80 Ci remaining in the aquifer. The total estimated amount of strontium-90 released to the river during reactor operations was 46 Ci. Present-day annual flux to the river has been computed to be on the order of 0.14 to 0.19 Ci/year (DOE 2001). The pump-and-treat operation removed 0.15 Ci of strontium-90 in CY04.

4.4.2 Plume Distributions

Figure 4-10 presents a historical comparison of the 1995 strontium-90 plume distribution in the 100-N Area based on sample results from 1994 through 1995 in approximately 30 wells (before the October 1995 startup of pump-and-treat operations) and the fall 2004 strontium-90 plume distribution. The difference between the two distributions is largely due to the number of data points used in contouring the plume but generally indicates that the plume has not changed much during the last 10 years.

4.5 QUALITY CONTROL

The data used for QC included offsite laboratory testing for total chromium, manganese, strontium-90, tritium, sulfate, and nitrate.

The highlights of QC data for the CY04 100-N Area sampling are summarized in the table below. Additional tables listing complete QC results are presented in Appendix I

Analyte	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Total chromium	5	NA	NA
Manganese	5	3	60%
Strontium-90	4	3	50%
Sulfate	5	5	100%
Tritium	5	5	100%
Nitrate	5	5	100%

NA = RPD evaluation cannot be performed

There are no functional guidelines for offsite laboratory replicate results, but the results correlated well based on the percentage of RPD <20%. The RPD calculation could not be performed on samples analyzed for total chromium because results were nondetects and were reported at the contract-required detection limit.

4.6 CONCLUSIONS

- ***RAO #1: Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the Columbia River are maintained. Protect associated potential human and ecological receptors using the river from exposure to radiological and nonradiological contaminants present in the unconfined aquifer. Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.***

  Results:

  - Pump-and-treat operations are assumed to reduce the hydraulic gradient between the Columbia River and the extraction wells. This activity is also assumed to decrease the volume of inland strontium-90-contaminated water entering the Columbia River. These assumptions need to be tested.
  - The capture area of the extraction, as configured in the numerical modeling, nearly matches the area predicted in DOE-RL (1996a). The pump-and-treat system is reducing net flux by approximately 96% based on a comparison of measured data and previous modeling results. However, elevated strontium-90 concentrations, especially in the near-shore aquifer, persist and do not appear to have declined as a result of pump-and-treat operations.

- The pump-and-treat system has removed minimal dissolved strontium-90 from the aquifer (1.6 Ci since startup, about 2% of the inventory in the aquifer). Natural decay and excavation of near-surface sources have been much more effective in removing strontium-90 and other radiological inventories than pump-and-treat operations.
- The pump-and-treat system is far less efficient than radioactive decay alone in reducing the amount of strontium-90 in the unconfined aquifer. Continuing to operate the pump-and-treat system in the future will cost an average of approximately $1 million/year (in 2004 dollars) (DOE-RL 2004c) but will increase the amount of strontium-90 removed from the aquifer by only about 10% above the amount removed by radioactive decay. Thus, a different and more cost-effective approach is needed to accomplish the objective of this RAO.

- ***RAO #2: Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater (by October 2004).***

  Results:

  - **Strontium-90 treatment technology evaluation:** As previously indicated, evaluation of alternative technologies to pump-and-treat was a need identified in the interim ROD (EPA et al. 1999) and was included as part of the interim remedy. Accordingly, a letter report on the evaluation of alternative strontium-90 treatment technologies and recommendations was prepared and delivered to Ecology in October 2004 (an interim ROD milestone; posted on the web site bhi-erc.com/Projects/risk/risk_library.htm). In addition, a public workshop was held on December 8, 2004, to discuss the findings and to solicit comments. The outcome of the December 8 meeting was to proceed with a field-scale treatability test phase of apatite sequestration and phytoremediation as a secondary or polishing option.

    Initial laboratory apatite sequestration studies conducted by PNNL during FY04 demonstrated the feasibility of in situ formation of calcium phosphate (apatite) in 100-N sediments by injection of solutions of citrate-complexed calcium and sodium phosphate. The method relies on biodegradation of the citrate, which in turn frees the calcium ions to form a calcium phosphate (apatite) coating on aquifer sediments. Strontium-90 becomes trapped or sequestered in the apatite solid phase. This approach allows the apatite to be more widely disseminated than with trenching methods, creating a broader treatment zone. By careful manipulation, timing, and location of the injection wells, treatment of the smaller portion of contaminated aquifer underlying the near-shore riverbed, as well as creating a permeable reactive barrier for treating the larger strontium-90 plume, may be possible. Field-scale testing is needed to confirm the laboratory results. Finalization of a treatability test plan initiated in December 2004 is pending favorable outcome of the FY05 laboratory results. Other minimally intrusive apatite emplacement options being considered include air injection and hydrofracture emplacement of apatite particles. Concerns expressed during the public workshop over the chemical injection approach included possible leaching effects (i.e., mobilization of some strontium-90 by the salt residue from the chemicals injected). Laboratory studies in FY05 are directed at resolving this issue before proceeding to the field-testing phase.

Greenhouse studies conducted by PNNL during 2004 successfully demonstrated extraction of strontium-90 by coyote willows from N-Springs sediments. Stakeholders and others expressed concerns about offsite dispersal of contaminated leaves and possible food-chain transfer. Accordingly, this issue will be resolved before proceeding to a field demonstration phase. Phytoremediation is the only currently known method that can actually remove strontium-90 from the critical near-shore zone. Without removal of the strontium-90 or fixation in place (apatite sequestration), the elevated strontium-90 concentrations in pore fluid at the shoreline will persist for years. The disadvantage of the phytoremediation method is that the annually harvested willows must be disposed as low-level waste in the ERDF.

- **Ecological receptor impacts:** The DQO process, including reconnaissance sampling to support the DQO effort, was completed during 2004 for the near-shore aquatic and riparian zone ecological risk assessment. The associated SAP (DOE-RL 2005a) will guide the CY05 field work for an ecological risk report that is due in October 2005. The SAP and DQO were coordinated with the River Corridor Baseline Risk Assessment (RCBRA) to avoid duplication of efforts and to ensure comparability of results.

  The associated DQO workbook and SAP are posted on web site www.bhi-erc.com/Projects/risk/risk_library.htm. The COCs include radionuclides, metals, and petroleum hydrocarbons. Results of the assessment will be used to determine the extent of potential strontium-90 treatment needed to protect aquatic and riparian biota along the 100-N Area shoreline. The ecological risk assessment SAP includes provision for metals and petroleum hydrocarbon sampling to evaluate the suspected impact of past diesel spills and miscellaneous sources of metals (e.g., hexavalent chromium).

- ***RAO #3: Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.***

  Results: The interim remedial action ROD (EPA et al. 1999) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls established in the interim action ROD for 100-NR-2 (EPA et al. 1999) was evaluated and summarized for implementation and effectiveness in 2003. The *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a) presents the results for the current review. In summary, the report found that institutional controls were maintained to prevent public access, as required.

4.7 RECOMMENDATIONS

- Conduct a short-term shutdown test of the pump-and-treat system to verify the magnitude of the assumed reduction in groundwater and strontium-90 flux to the river. This information is needed to support a proposed treatability test of a natural gradient, strontium-90 sequestration barrier in the aquatic/riparian zone near the old N springs location.

- Determine the cause of the decline in strontium-90 removal efficiency and evaluate possible corrective actions. This should include the possible impact of a change in influent chemical composition due to encroachment of the high sulfate plume from the old 1324-N crib on the southwestern side of the capture zone. This investigation can be timed to occur during the proposed short-term shutdown planned for July 15 through November 15, 2005. The investigation of corrective actions should include possible reconfiguration of extraction/injection well locations if the sulfate plume encroachment hypothesis is confirmed.

Figure 4-1. 100-N Area Operable Unit Location.

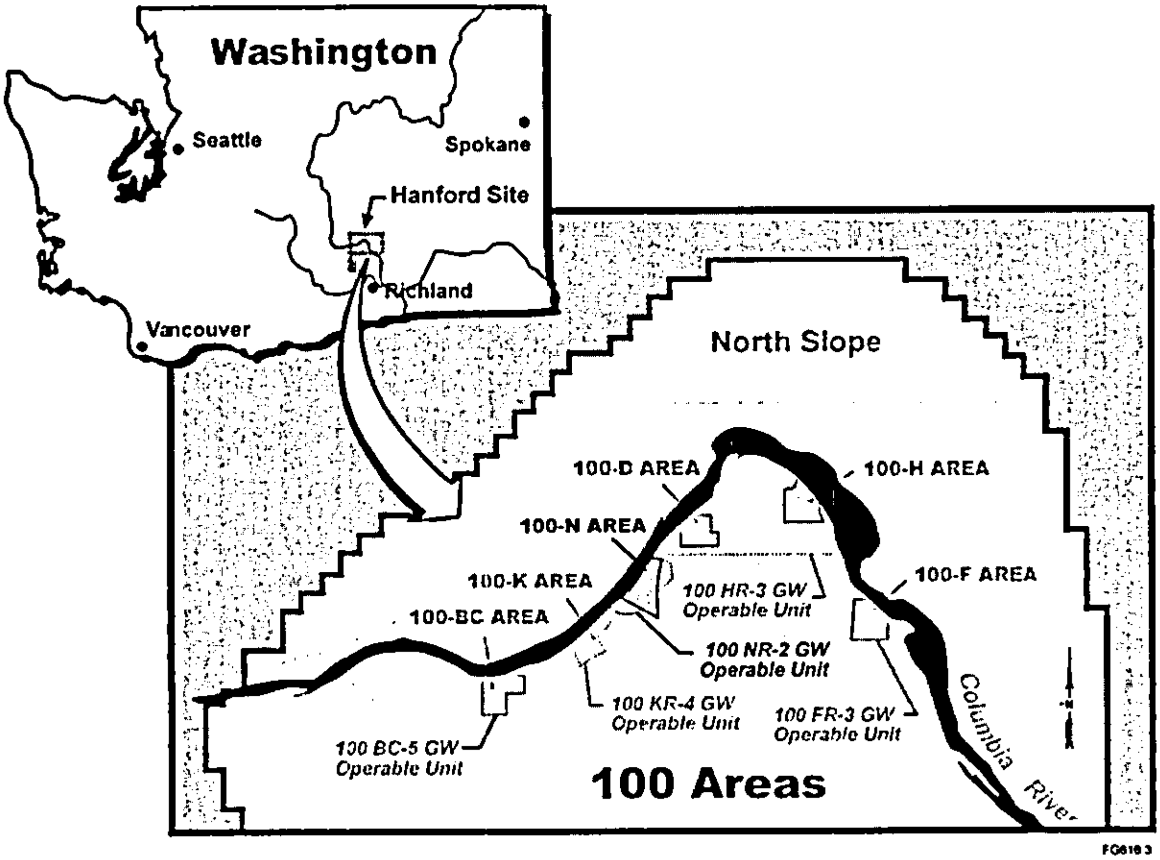
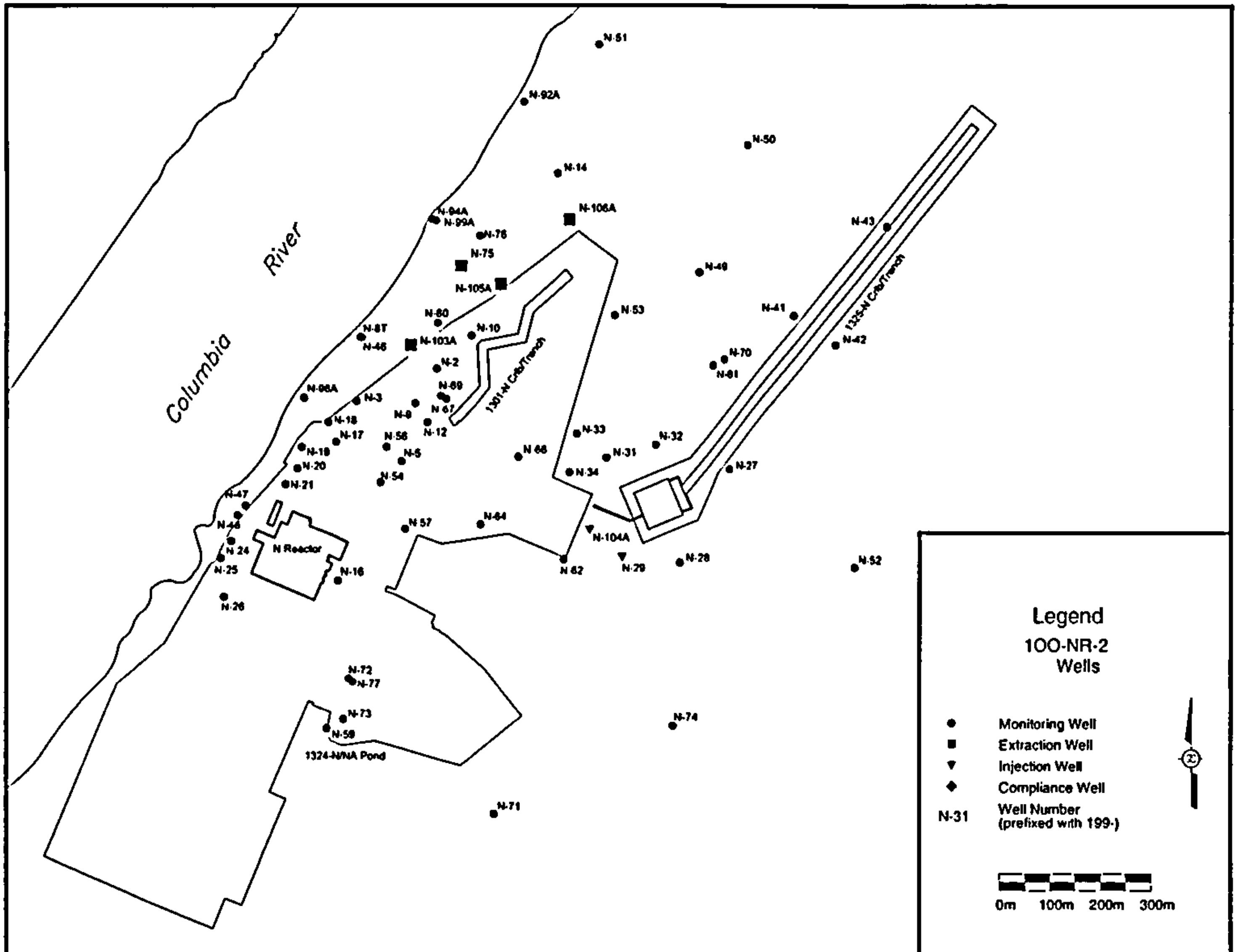


Figure 4-2. 100-NR-2 Operable Unit Wells and Seeps.



100-NR-4

Figure 4-3. 100-NR-2 Pump-and-Treat System Schematic.

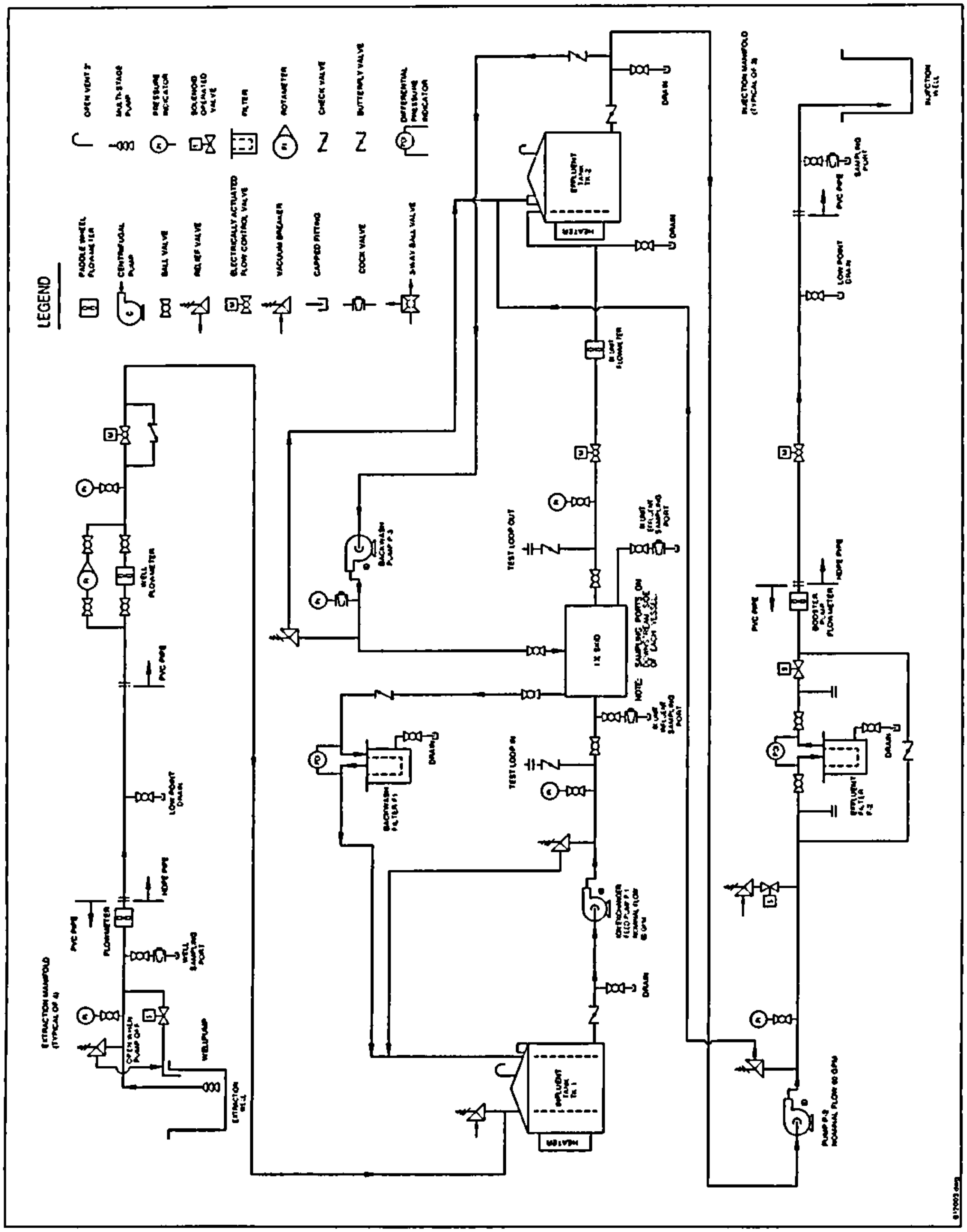
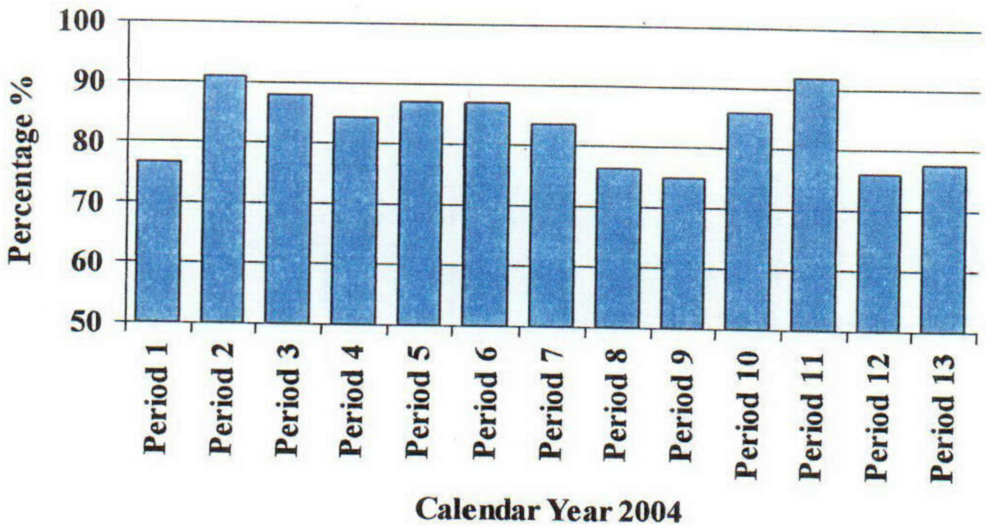


Figure 4-4. 100-NR-2 System Availability and On-Line Percentages for Calendar Year 2004.



NOTE: Clino-periods 1-10 average 28-day cycles; 11 to 13 are 21 days.
Performance measurement based upon mid-point sample for the clino-period.

Summary of system availability:	
Total possible run-time (hours)	8,784
Scheduled downtime (hours)	337
Planned operation (hours)	8,447
Unscheduled downtime (hours)	830.5
Total time on-line	7,616.5
Total availability (%)	86.7
Scheduled system availability (%)	90.2

Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].

Total availability[(total possible run-time – scheduled and unscheduled downtime) / total possible run-time).

Figure 4-5. 100-NR-2 Pump-and-Treat Trends of Influent and Effluent Strontium-90 Concentrations for Calendar Year 2004.

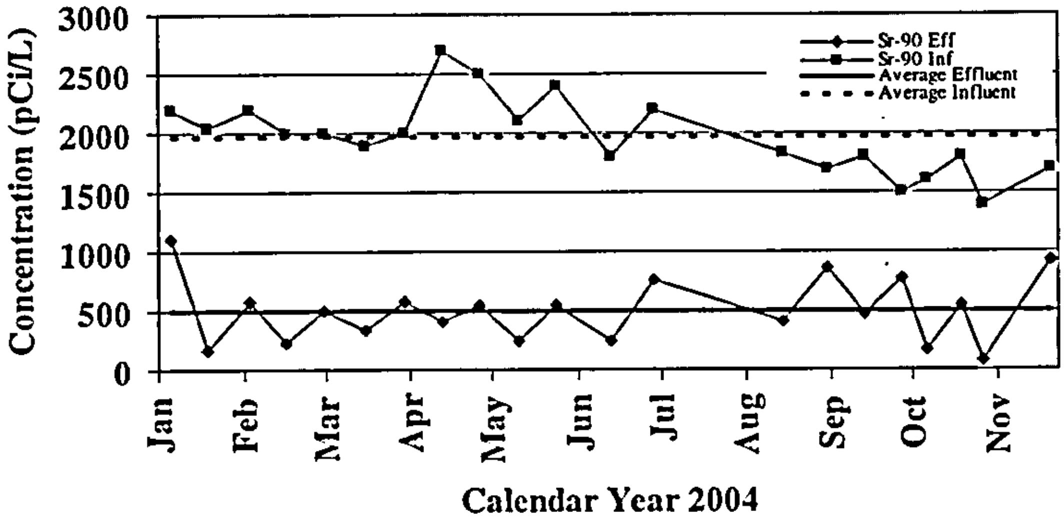


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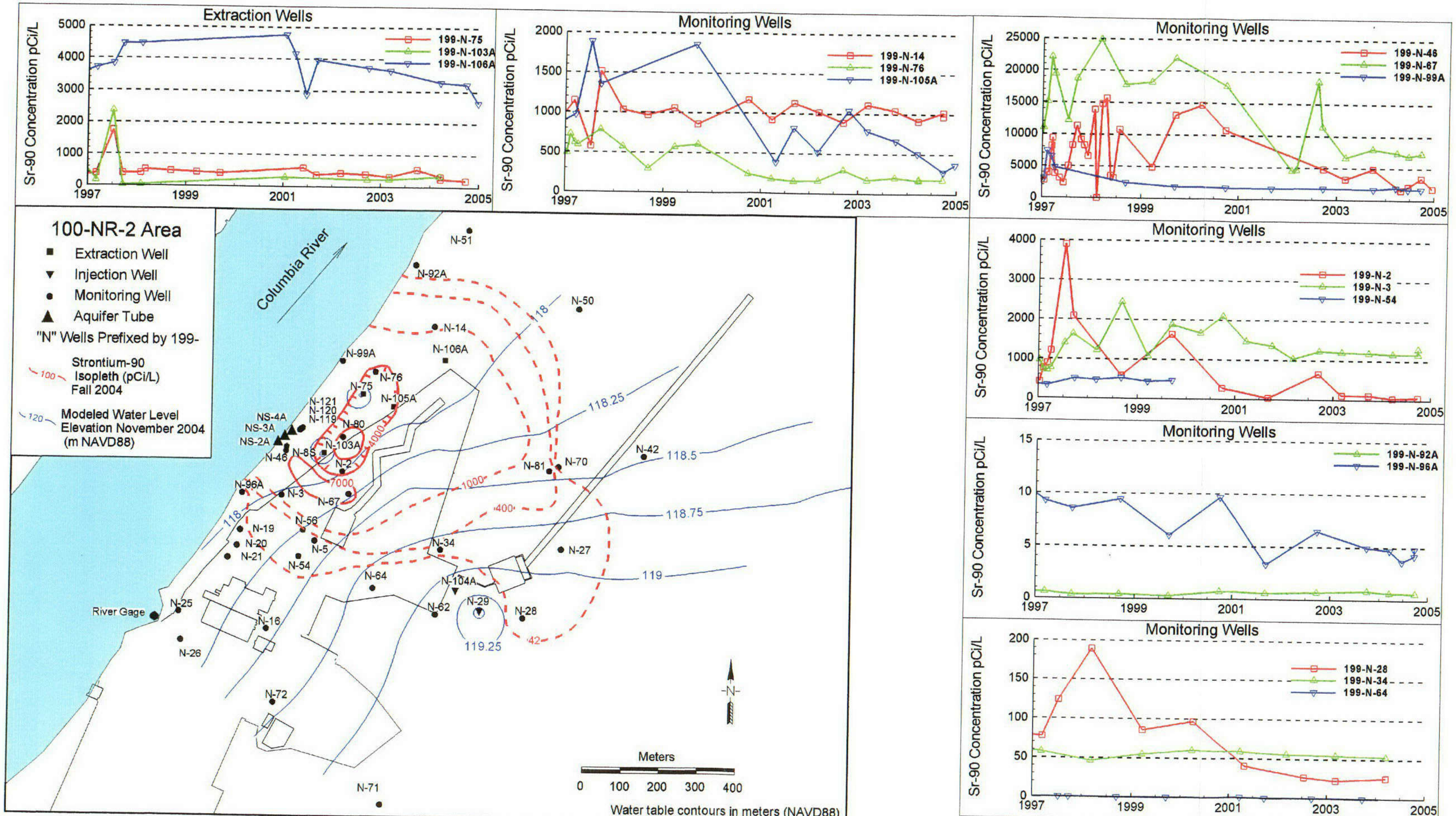
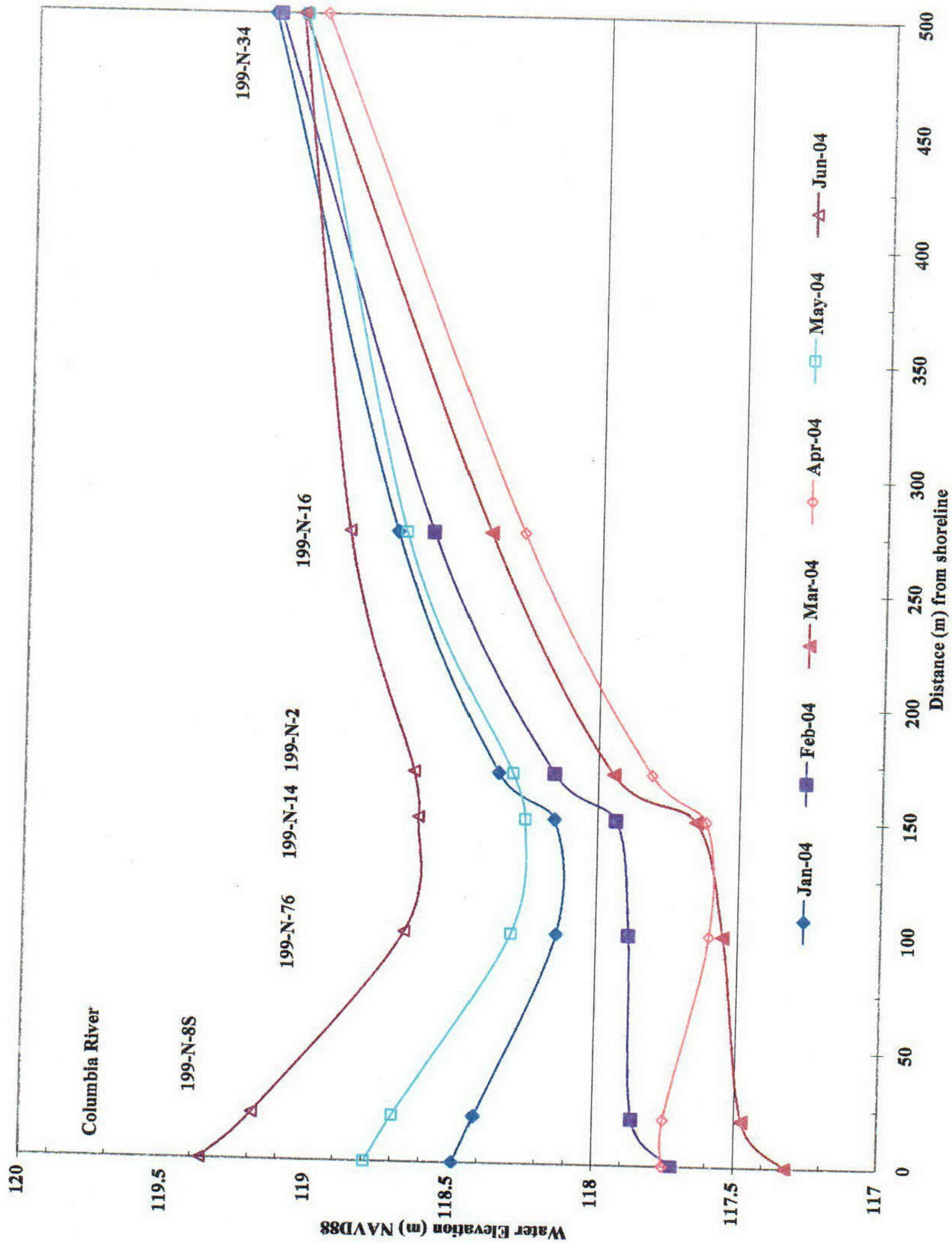
Figure 4-6. 100-NR-2 Strontium-90 Plume, Fall 2004.



*Well 199-N-105A is used as a monitoring well and backup extraction well.

Figure 4-7. Water Elevation Versus Distance from the Columbia River in 100-N Area Wells.



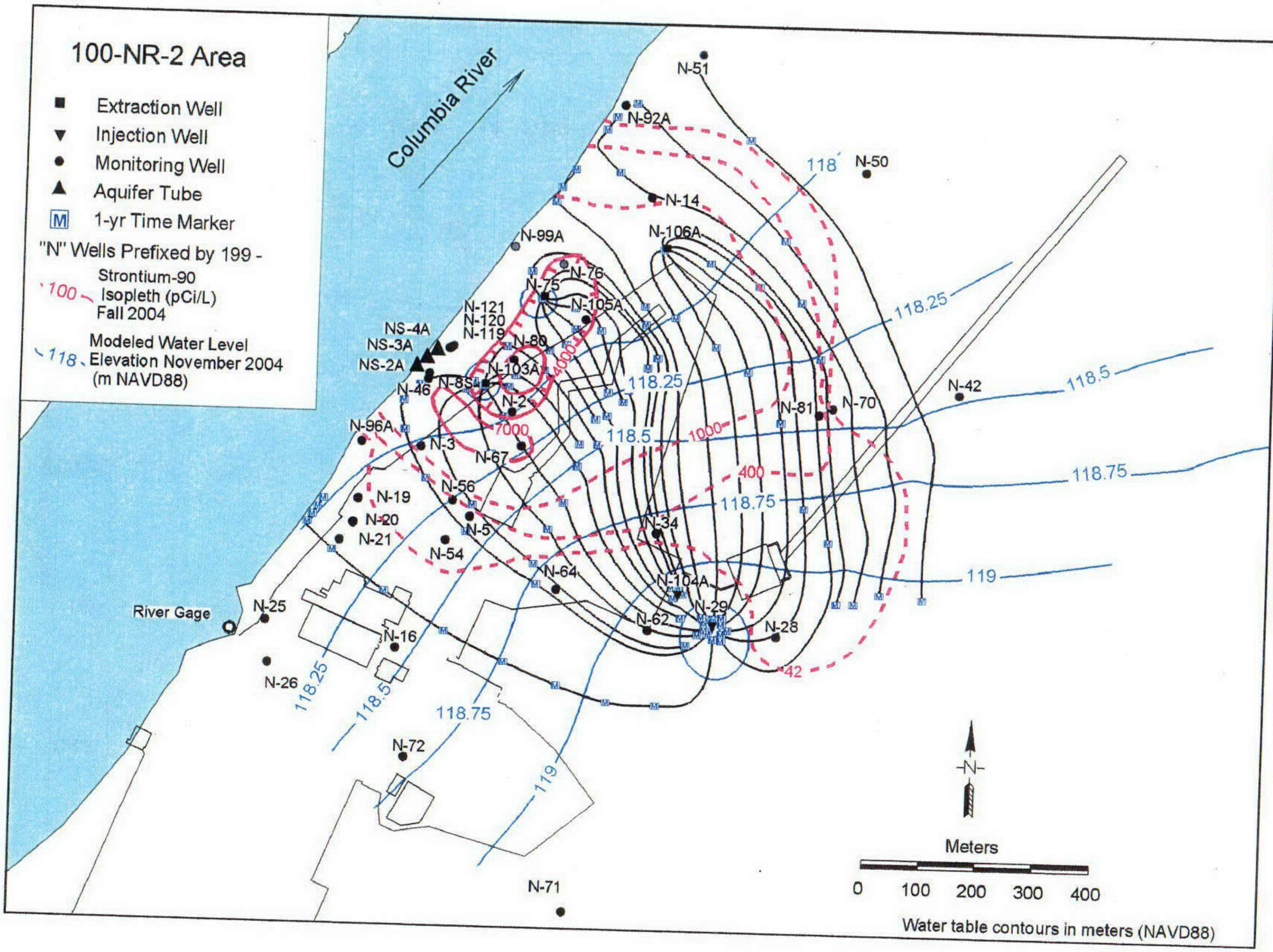
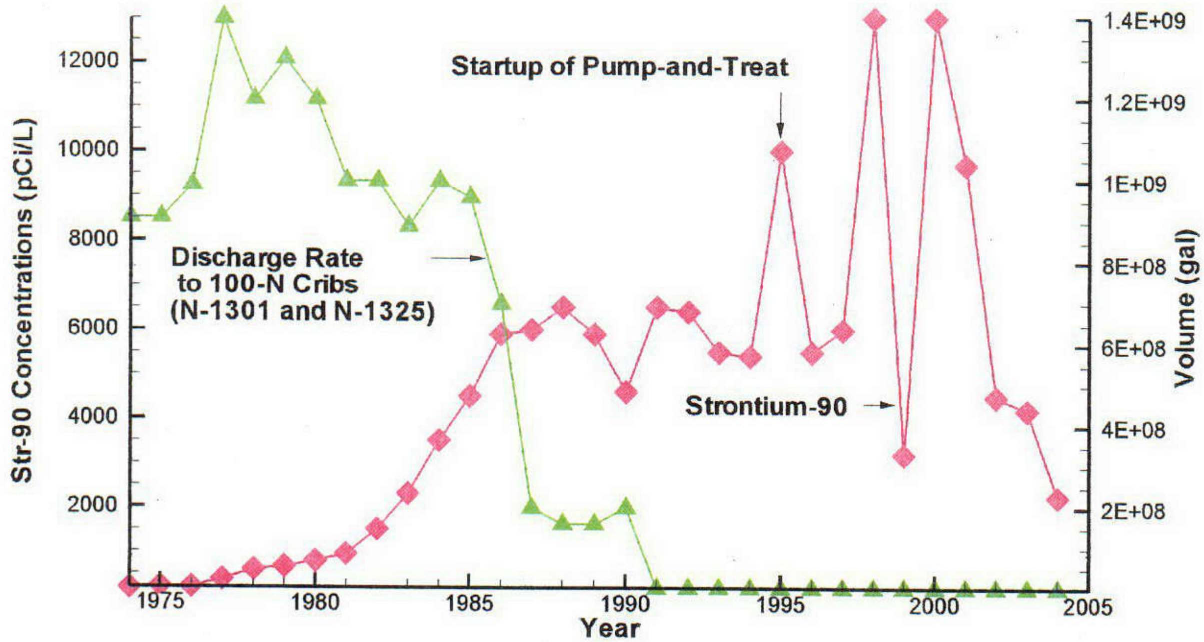


Figure 4-8. Estimated Steady-State Hydraulic Capture Zone Developed by 100-NR-2 Operable Unit Extraction Wells.

Figure 4-9. Strontium-90 and Tritium in Near-Shore Monitoring Wells 199-N-8 and 199-N-46.



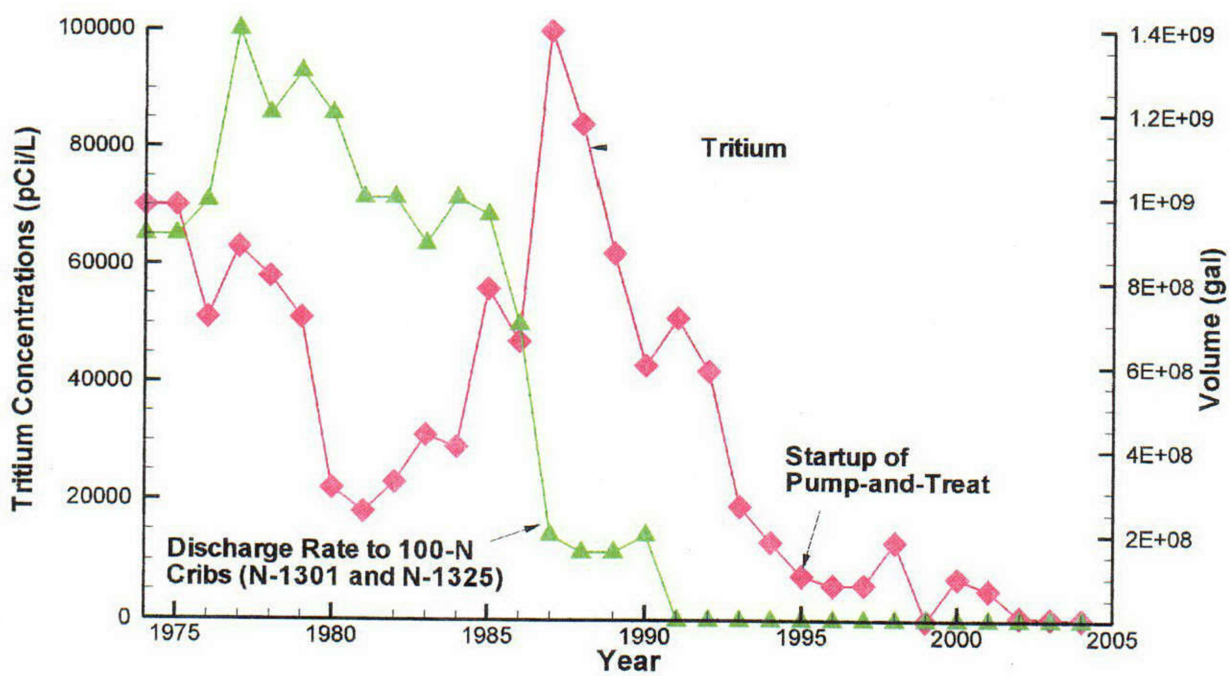


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Figure 4-10. 100-NR-2 Operable Unit Strontium-90 Plume Map, 1995 and 2004.

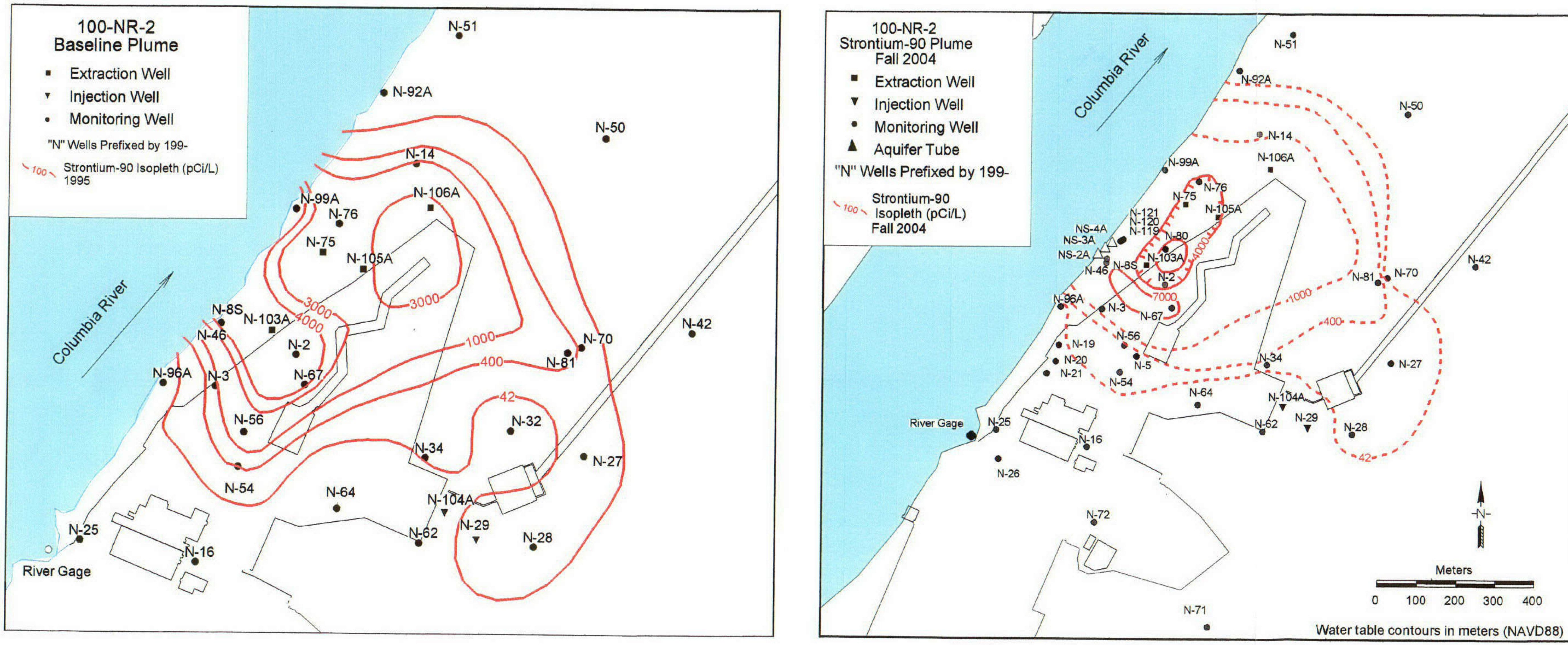

Table 4-1. 100-NR-2 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Extraction Rate L/min	Injection Rate L/min	Measured Elevation, Nov. 2004 (m NAVD88a)	Modeled Elevation, Nov. 2004 (m NAVD88a)
199-N-75	45.4	--	--	117.21
199-N-103A	53	--	118.00	117.11
199-N-105A	0	--	116.12	117.91
199-N-106A	107.9	--	117.02	117.80
199-N-104A	--	130.6	124.18	119.21
199-N-29	--	208.2	121.67	120.00
199-N-2	--	--	118.09	117.98
199-N-3	--	--	118.10	118.02
199-N-8S	--	--	117.90	117.88
199-N-14	--	--	117.81	117.88
199-N-16	--	--	118.41	118.44
199-N-34	--	--	118.96	118.83
199-N-50	--	--	118.01	118.03
199-N-72	--	--	118.69	118.70
199-N-76	--	--	117.67	117.85
199-N-92A	--	--	118.26	117.82
199-N-99	--	--	--	117.84

[a] NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

-- = No data available

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5.0 PUMP-AND-TREAT SYSTEM COST DATA

Actual costs for the 100-HR-3, 100-KR-4, and 100-NR-2 pump-and-treat systems were recorded in FH's Hanford Data Integrator. The data are used to determine the actual capital and expense costs associated with a specific activity during the FY. Specific activities are briefly described below:

- **Capital design:** Includes design activities to construct the pump-and-treat systems and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the pump-and-treat system.
- **Project support:** Includes project coordination-related activities and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation.
- **Operations and maintenance:** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes costs associated with routine field screening and engineering support as required during the course of pump-and-treat operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis as required in accordance with the 100-HR-3 and 100-KR-4 interim action work plan (DOE-RL 1996b).
- **Waste management:** Includes the cost for the management of spent resin at 100-HR-3 and 100-KR-4 and spent clinoptilolite in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. It includes waste designation sampling and analysis. Also included are resin regeneration costs and new resin purchase.

Costs are burdened and are based on actual operating costs incurred during FY04. A comparison between FY03 and FY04 costs is presented in the following sections.

5.1 100-HR-3 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-HR-3 pump-and-treat system is presented in Figure 5-1. Total construction and operation costs for FY04 are higher when compared to FY03. Cost increases are attributed to capital construction costs and increased operations and maintenance costs. As shown in Figure 5-1, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to operations and maintenance (41%), waste management (19%), capital construction (19%), project support (8%), design (8%) and performance monitoring (5%). Based on the total FY04 cost ($2,576,000), the yearly production rate of 317.7 million L and 33.6 kg of hexavalent chromium removed, the annual treatment costs equate to $0.008/L or $74.66/g of hexavalent chromium removed. These treatment costs are similar to FY02 treatment costs but are significantly higher than FY03.

A second pump-and-treat system (DR-5, which includes three extraction wells, a separate treatment system, and injection wells) was constructed in the D/DR Reactor area. As presented in Figure 5-2, the total FY04 costs for the new system were $2,090,100. The cost breakdown indicates that the majority of the cost was incurred for treatment system capital construction

(77%), followed, in decreasing order, by design (11.7%), project support (8.4%), operations and maintenance (2.3%), performance monitoring (0.08%) and waste management (0.03%).

5.2 100-KR-4 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-KR-4 pump-and-treat system is shown in Figure 5-3. Compared to FY03, the total construction and operations costs were slightly lower in FY04. As shown in Figure 5-2, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to operations and maintenance (52%), waste management (22%), project support (10%), design (8%), performance monitoring (4%), and treatment system capital construction (4%). Based on the FY04 cost ($2,147,200), the yearly production rate of 500 million L and 29.6 kg of hexavalent chromium removed, the annual treatment costs equate to $0.004/L, or $72.53/g of hexavalent chromium removed. The treatment costs for FY04 compared to FY03 are the same per liter of groundwater processed but are slightly higher per gram of hexavalent chromium removed due to the reduction in total quantity removed.

5.3 100-NR-2 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-NR-2 pump-and-treat system is presented in Figure 5-4. Compared to FY03, total construction and operations costs were significantly higher in FY04. Cost increases are attributed to higher cost for design, project support, operations and maintenance, and performance monitoring costs. As shown in Figure 5-4, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to operations and maintenance (56%), project support (33%), performance monitoring (8%), and waste management (3%). Based on the FY04 cost ($989,700), the yearly production rate of 107.2 million L and 0.1572 Ci of strontium-90 removed, the annual treatment costs equate to $0.009/L, or $6,294,600/Ci of strontium-90 removed. The treatment costs were significantly higher in FY04 compared to FY03.

Figure 5-1. 100-HR-3 Pump-and-Treat System Costs. (2 sheets)

Cost Breakdown for 100-HR-3 Pump-and-Treat Construction and Operations									
Description	Actual Costs (Dollars x 1,000)								
	1996	1997	1998	1999	2000	2001[a]	2002[b]	2003	2004
Design	2,040.0	--	--	--	--	97.7	15.4	8.1	196.1
Treatment system capital construction	164.0	--	--	--	57.7	(36.1)	750.3	--	496.6
Project support	--	741.0	264.9	265.3	276.7	225.8	309.3	229.8	211.8
Operations and maintenance	948.0	3,437.0	1,533.3	1,650.8	799.1	739.2	816.6	733.7	1,049.5
Performance monitoring	--	259.0	0.4	--	173.7	219.9	120	163.2	120.3
Waste management	--	--	--	--	895.3	424.9	720.1	877.2	501.7
Totals	**$3,152**	**$4,437**	**$1,799**	**$1,916**	**$2,202**	**$1,671**	**$2,732**	**$2,012**	**$2,576**

- = not available

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

100-HR-3 Pump-and-Treat System Fiscal Year 2004 Cost Breakdown (by Percentage)

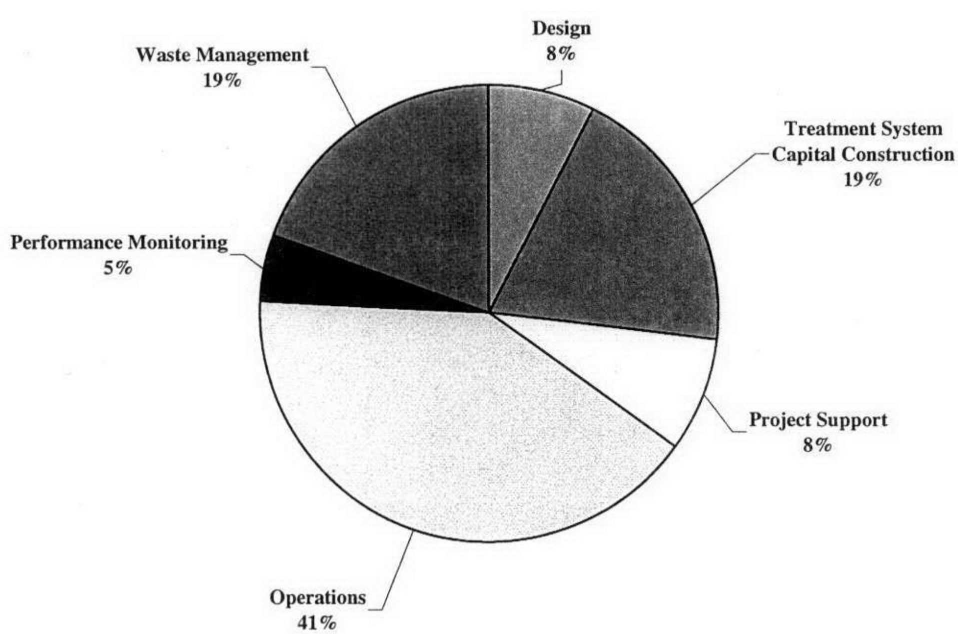


Figure 5-1. 100-HR-3 Pump-and-Treat System Costs. (2 sheets)

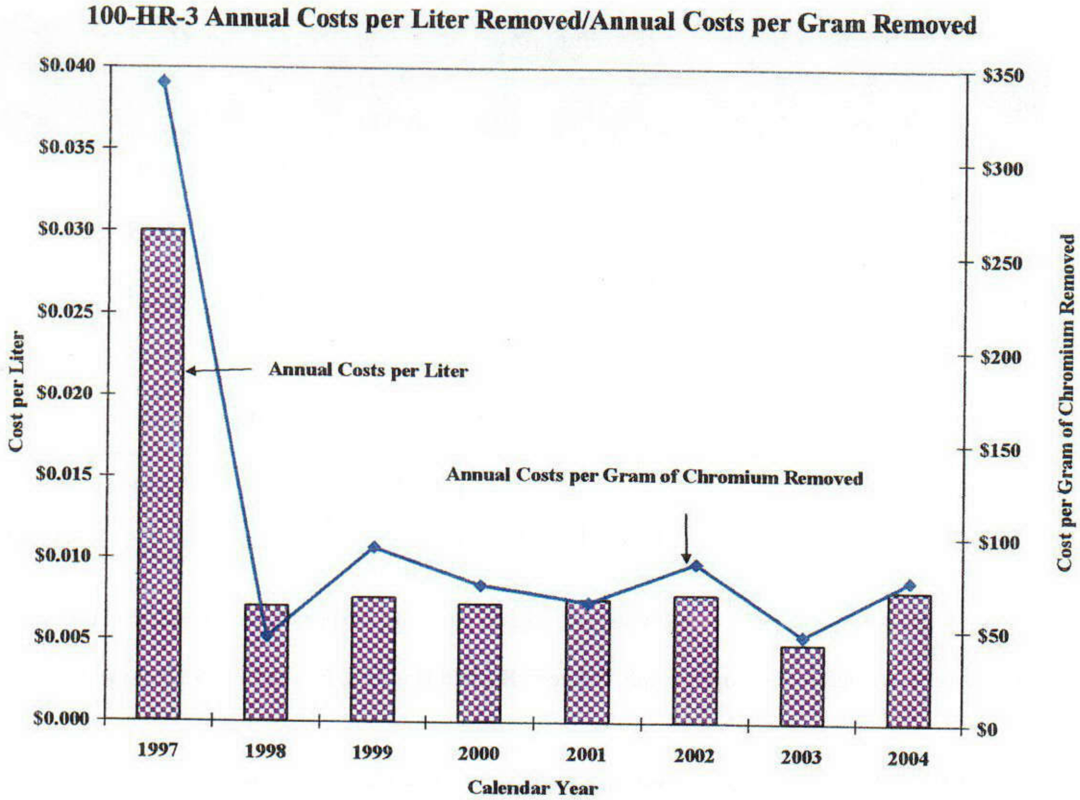


Figure 5-2. DR-5 Pump-and-Treat System Costs.

Cost Breakdown for DR-5 Pump-and-Treat Construction and Operations

Description	Actual Costs (Dollars x 1,000)
	2004
Design	244
Treatment system capital construction	1,620.3
Project support	175.1
Operations and maintenance	48.3
Performance monitoring	1.7
Waste management	.7
Total	**$2,090.1**

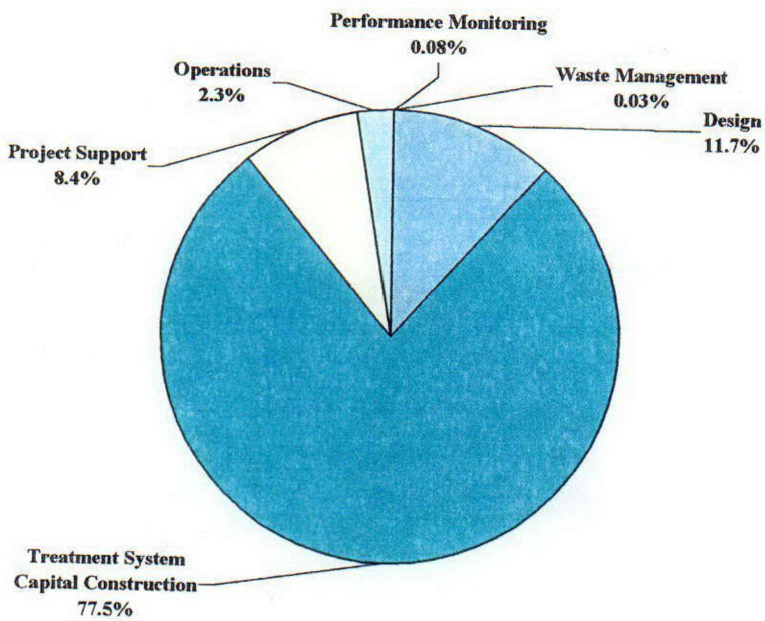


Figure 5-3. 100-KR-4 Pump-and-Treat System Costs. (2 sheets)

Cost Breakdown for 100-KR-4 Pump-and-Treat Construction and Operations									
Description	Actual Costs(Dollars x 1,000)								
	1996	1997	1998	1999	2000	2001[a]	2002[b]	2003	2004
Design	1,060.0	163.0	85.4	0.2	--	96.5	55.2	70.8	163.9
Treatment system capital construction	81.0	--	--	--	109.1	(0.1)	860.1	379.9	94.2
Project support	--	327.0	208.4	157.2	143.0	188.2	257.8	171.0	211.8
Operations and maintenance	869.0	2,525.0	1,028.9	717.4	538.0	578.6	771.9	789.7	1,118.2
Performance monitoring	--	382.0	1.4	--	111.2	122.6	124.6	119.7	83.3
Waste management	--	--	--	--	481.8	367.5	343.3	684.7	475.8
Totals	**2,010**	**$3,397**	**$1,324**	**$875**	**$1,383**	**$1,353**	**$2,413**	**$2,216**	**$2,147**

- = not available

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

100-KR-4 Pump-and-Treat System Fiscal Year 2004 Cost Breakdown (by Percentage)

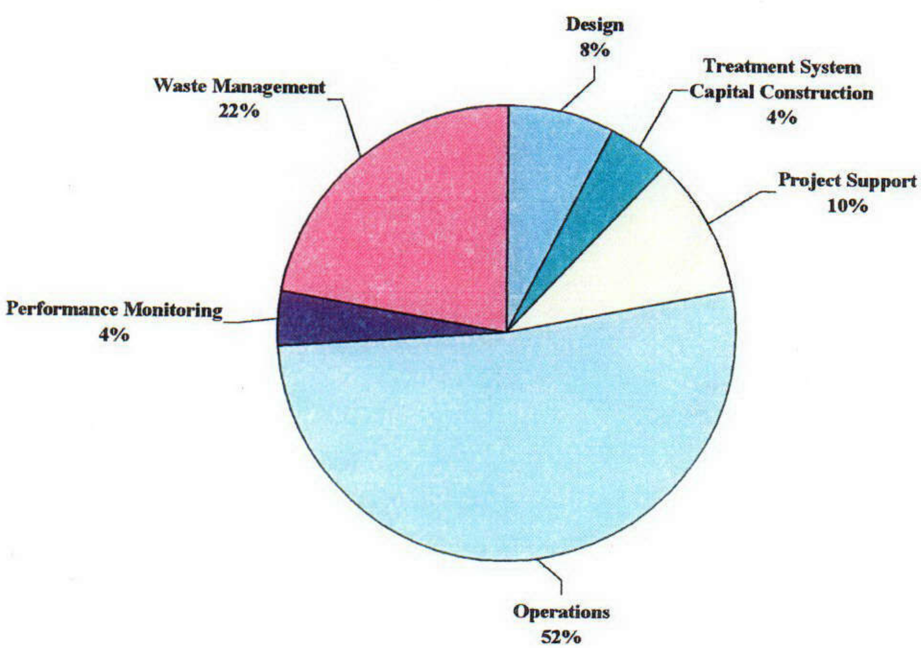


Figure 5-3. 100-KR-4 Pump-and Treat System Costs. (2 sheets)

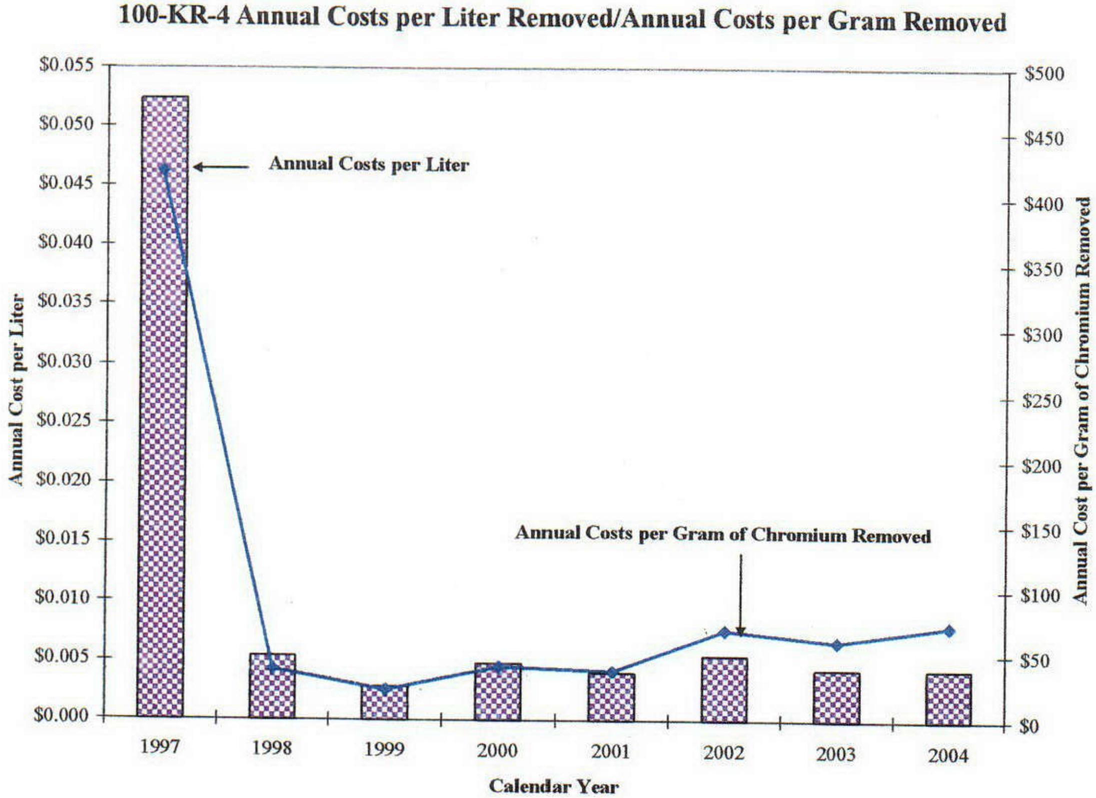


Figure 5-4. 100-NR-2 Pump-and Treat System Costs. (2 sheets)

Cost Breakdown for 100-NR-2 Pump-and-Treat Construction and Operations									
Description	Actual Costs (Dollars x 1,000)								
	1996	1997	1998	1999	2000	2001[a]	2002[b]	2003	2004
Design	2,289.4	951.8	32.6	0.2	--	--	--	--	--
Treatment system capital construction	55.0	--	-	--	--	--	--	--	--
Project support	--	119.4	136.0	113.1	96.3	183.5	219.4	133.0	329.7
Operations and maintenance	2,622.7	1,027.8	425.2	657.4	462.2	631.5	631.8	604.3	553.0
Performance monitoring	--	--	--	--	82.6	83.1	72.4	51.6	79.6
Waste management	--	--	--	--	131.6	112.5	100	45.4	27.4
Totals	**$4,967**	**$2,099**	**$594**	**$771**	**$773**	**1,011**	**$1,024**	**$834**	**$989.7**

- = not available

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

100-NR-2 Pump-and-Treat System Fiscal Year 2004 Cost Breakdown (by Percentage)

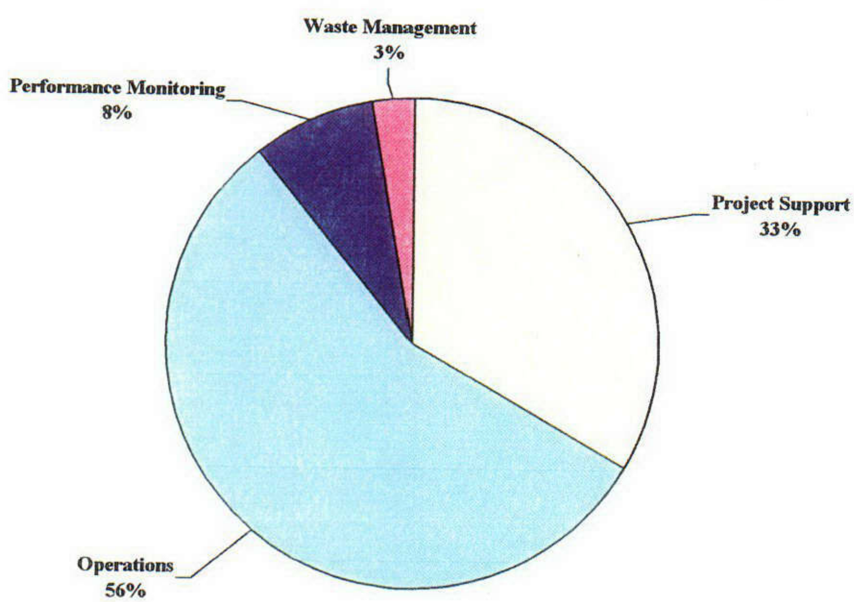
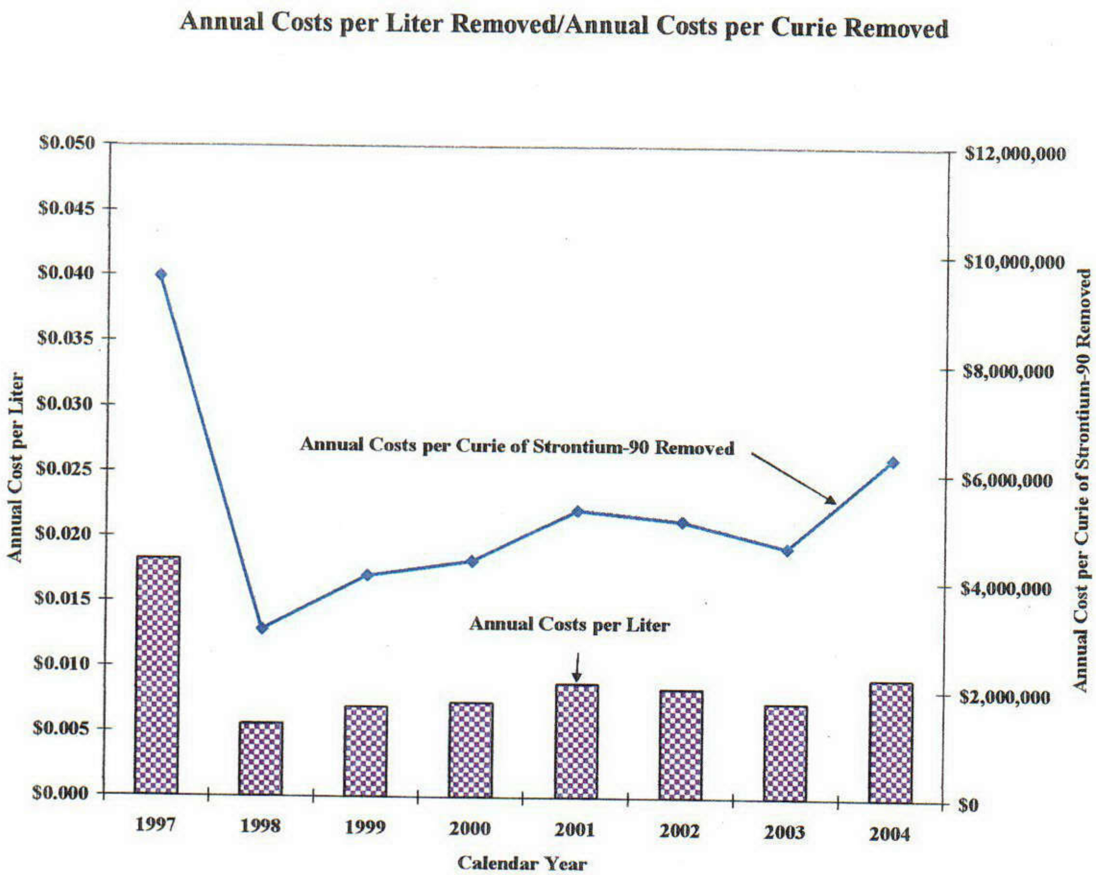


Figure 5-4. 100-NR-2 Pump-and Treat System Costs. (2 sheets)



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